

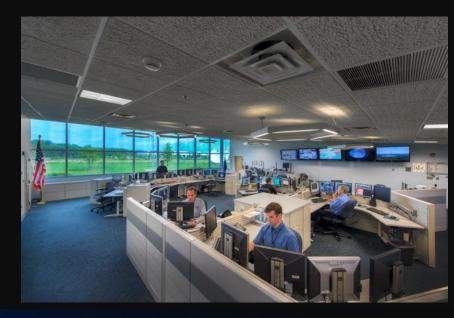
# **Tonight's Topics**

- NWS Hydrology Overview
- Flood Facts & Flood Safety
- "Hydrology 101"
- Flood Forecasting / Meteorology
- Types of Flooding
- NWS Products

#### Break

- Observations
- What's a "Flood Spotter"?
- What to Report
- Flood History
- Flood Warning Case Reviews
- Review







#### **National Weather Service Mission**

Provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.



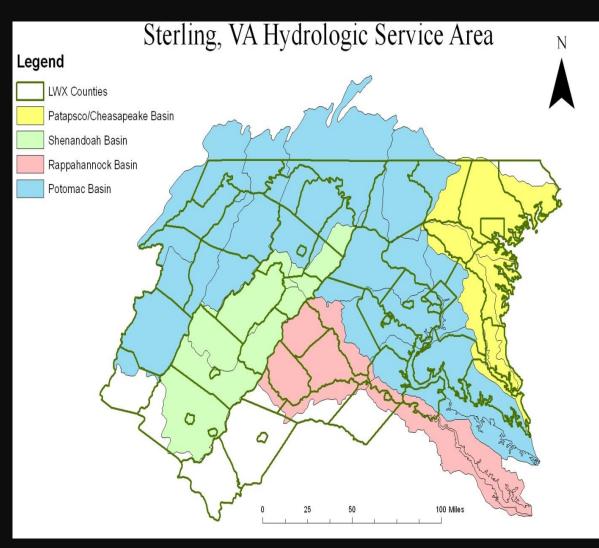
#### **NWS Service Delivery**

**Facilities** 



# **Areas of Responsibility**

- County Warning Area (CWA)Flash Flood
  - 43 Counties in 3 states
  - District of Columbia
  - 12 Independent Cities
  - MD Chesapeake Bay
- Hydrologic Service Area (HSA)River Flood
  - Potomac Basin
  - Shenandoah Basin
  - Rappahannock Basin
  - West Chesapeake





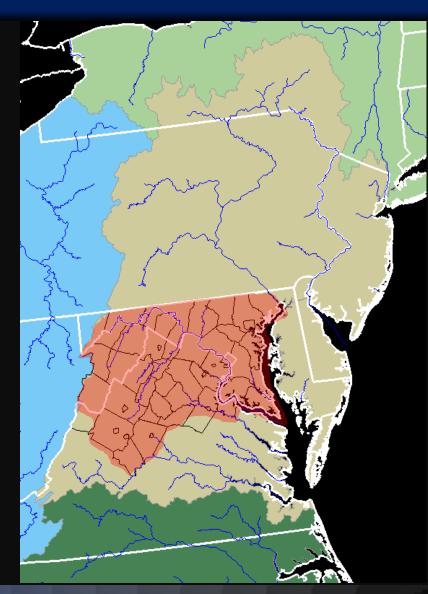
# **Hydrologic Staffing**

#### Weather Forecast Office

- 1 Service Hydrologist
  - Not all offices have this!

#### River Forecast Centers

- Hydrologist-in-Charge
- Service Coordination Hydrologist
- Developmental & Operations Hydrologist
- 3 or 4 Hydrometeorologists
- 4 to 9 Hydrologists

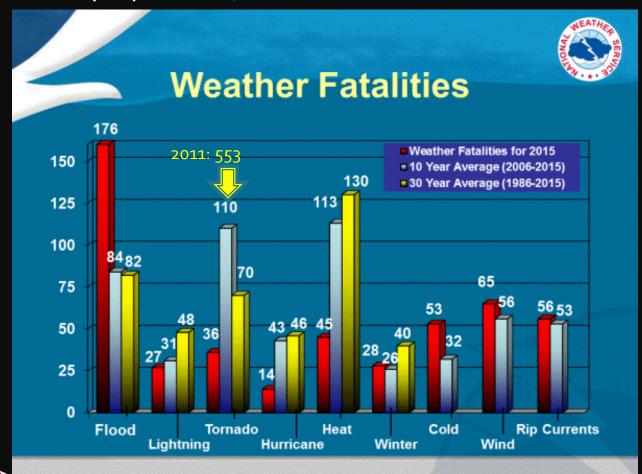


# Don't let this be you! (Or anyone you know.)



### Floods – a major weather killer

On a long-term basis, floods are the #2 cause of death when weather plays a role, behind heat.



### Flood Facts

- Most flood fatalities:
  - occur in cars
  - occur at night

• are the result of bad decisions

Upper Marlboro, MD & Fairfax, VA — Sept. 2011



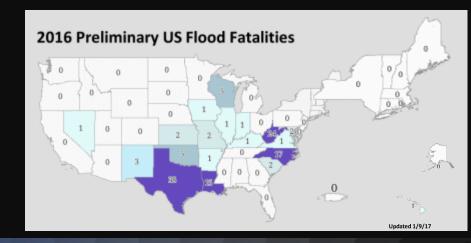






### Flood Fatalities

- In 2016, there were 123 flood fatalities (50% above the long-term average).
  - 38 of these were in Texas; 24 in West Virginia; 2 in Ellicott City
  - Two-thirds were male
    - This is consistent year after year
  - Nearly two-thirds (61%) were vehicle-related
    - This is also consistent year after year
  - Multiple fatality incidents:
    - 5 were all in <u>one house</u> that was inundated by flood water
    - 9 soldiers were killed when their truck overturned in a rain-swollen creek during a military training exercise



# Flood Damages

- Average: \$8 billion per year!
  - 2016: \$8.7 billion in Louisiana in August alone!
- In 2014 and 2015, 2/3 of all Presidentially-declared disasters were at

least in part flood-related (3/4 in 2016!)



Ellicott City, MD 2016

# Flood Safety

#### Take Appropriate Action!

Better forecasts and earlier warnings won't help prevent loss of life and property unless people act.

Plan ahead – Identify where to go if told to evacuate.
 Choose several places (a friend's home or a motel, or a

designated shelter)

Never try to drive, swim, walk, or run through a flooded area

Children should not play in flooded areas

River Road, Falmouth, VA
March 2011



# Turn Around, Don't Drown!

- If you come upon flood waters, STOP! TURN AROUND AND GO ANOTHER WAY!
- Only 6 inches of fast-moving water can knock you off your feet
- 2 feet of water will float an average size car...less water for smaller cars
- Bottom line: <u>never</u> assume there is a safe way to drive through water



# The Physics of Floating Cars



**Vehicle weights:** 

Mitsubishi Mirage: 1,973 pounds

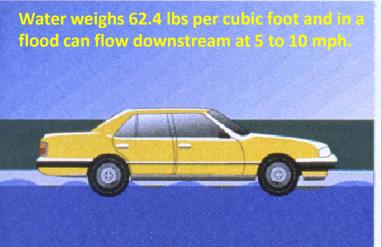
Ford Fiesta: 2,537 pounds

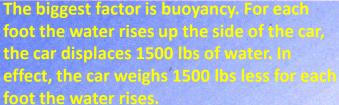
Toyota Corolla: 2,800 pounds

Honda Accord: 3,336 pounds

Ford F-150: 4,850 pounds

Chevy Suburban: 5,808 pounds







When a vehicle stalls in the water, the water's momentum is transferred to the car. For each foot the water rises, 500 lbs of lateral force are applied to the car.



Two feet of water will carry away most automobiles!







# The Physics of Floating Cars



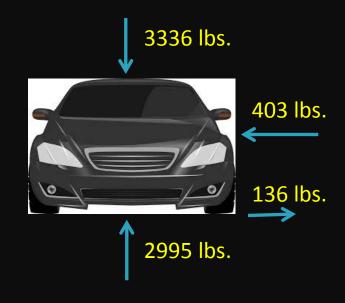
- The Honda Accord weighs 3,336 pounds
- 1 foot of water displaced by this vehicle weighs (6 \* 16 \* 1 \* 62.4) = 5990 pounds

- Water Depth = 1 foot
- Width: 6 feet
- Length: 16 feet
- Clearance: 6 inches
- Weight: 3,336 pounds
- ▶ Net Depth = 0.50 foot

Net Weight: 3,336 lbs - 2,995 lbs = 341 lbs

Friction Force:  $0.4 \times 341$  lbs = 136 lbs

136 lbs is LESS than the 403 lbs of stream force, so unless you and all the extra things in your vehicle weigh 267 pounds, your car will begin to float!





### **Not Just Hazards for Cars**

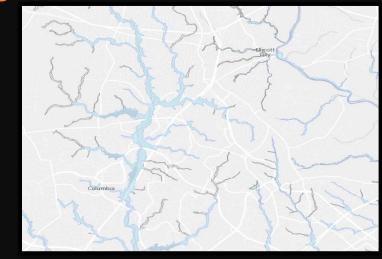


WFTS-TV

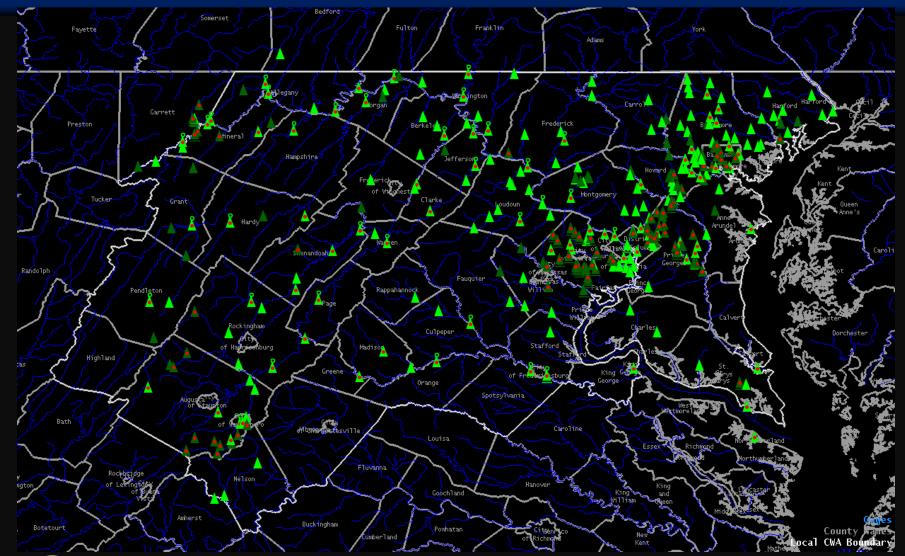


#### **Know Your Risk**

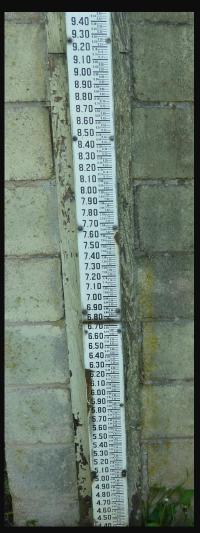
- Check the FEMA Flood Maps to see if you are in a flood zone...
  - Maryland: <a href="http://www.mdfloodmaps.net">http://www.mdfloodmaps.net</a>
  - Virginia: <a href="http://cmap2.vims.edu/VaFloodRisk/vfris2.html">http://cmap2.vims.edu/VaFloodRisk/vfris2.html</a>
  - West Virginia: <a href="http://www.mapwv.gov/flood/">http://www.mapwv.gov/flood/</a>
  - DC: <a href="https://doee.dc.gov/floodplainmap">https://doee.dc.gov/floodplainmap</a>
  - National: <a href="https://www.floodsmart.gov">https://www.floodsmart.gov</a>
- Flooding is not limited to these flood zones! Always consider flood insurance!



# River & Lake Gauges

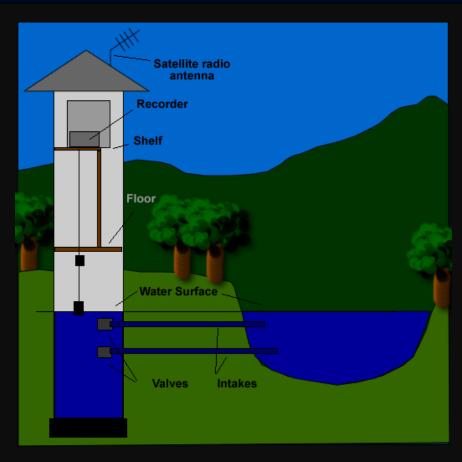


#### How are water levels measured?





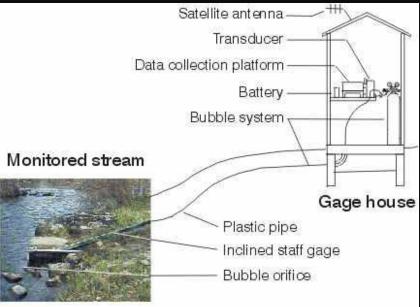
From left: Staff Gauge Crest Gauge Stilling Well / Float





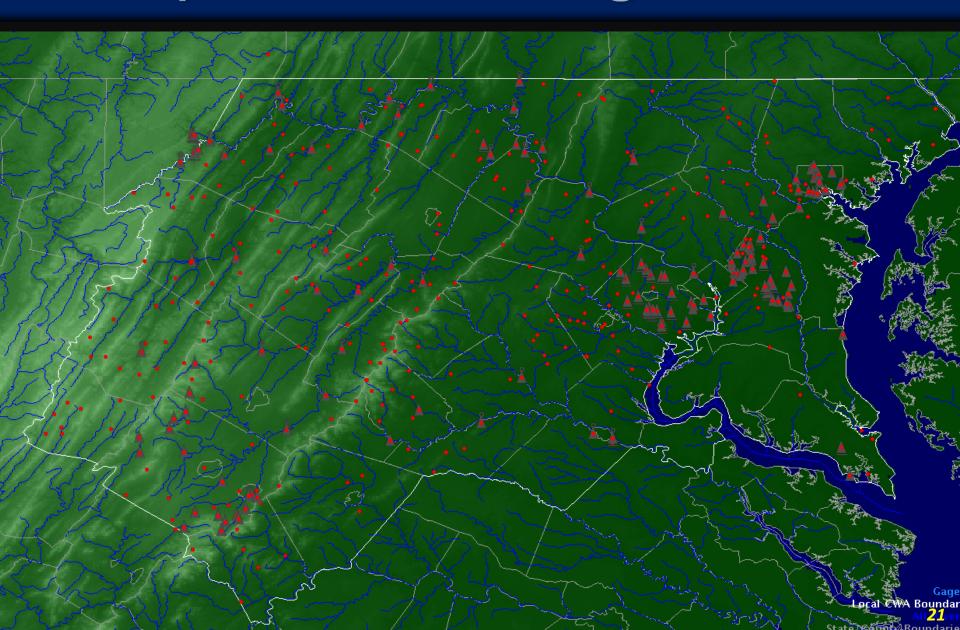
#### How are water levels measured?



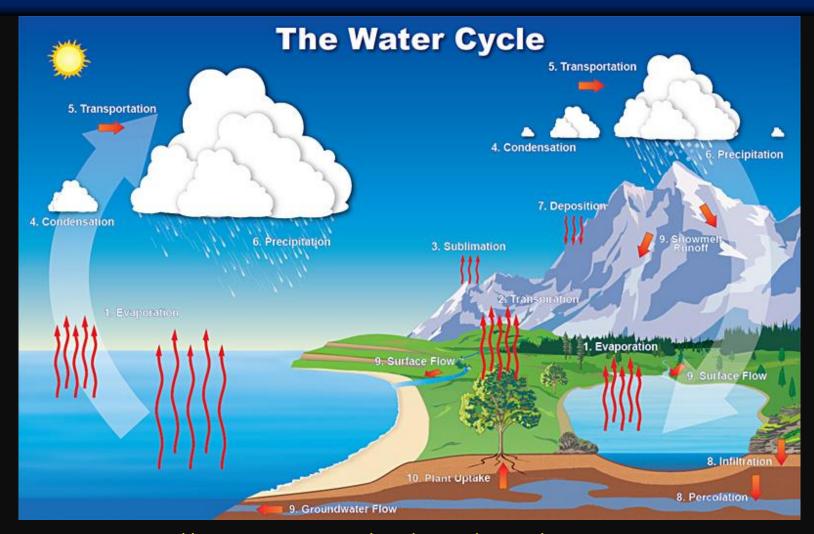


# From left: Wire Weight Gauge Radar Gauge Pressure Transducer / "Bubbler"

# **Precipitation Monitoring**



# **Basic Hydrology**

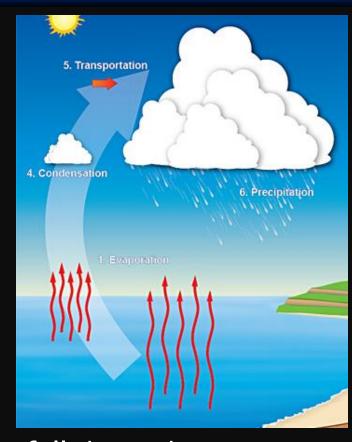


http://polaris.umuc.edu/cvu/envm/hydro/hydrologic.swf



# Precipitation in the Water Cycle

- The air must be nearly saturated.
- Cloud droplets or ice crystals form through condensation on small particles (often minerals in the air)
- These droplets/crystals then grow in size
- For precipitation to occur, cloud elements must increase in size until their falling speeds exceed the upward motion in the air



Also, the precipitation must be able to fall through any drier air that exists between the cloud and the ground.

### How do we forecast flood potential?

- Pre-event assessment "antecedent conditions"
- Consider areas more prone to flooding
- Forecast expected rainfall
- Put it all together!



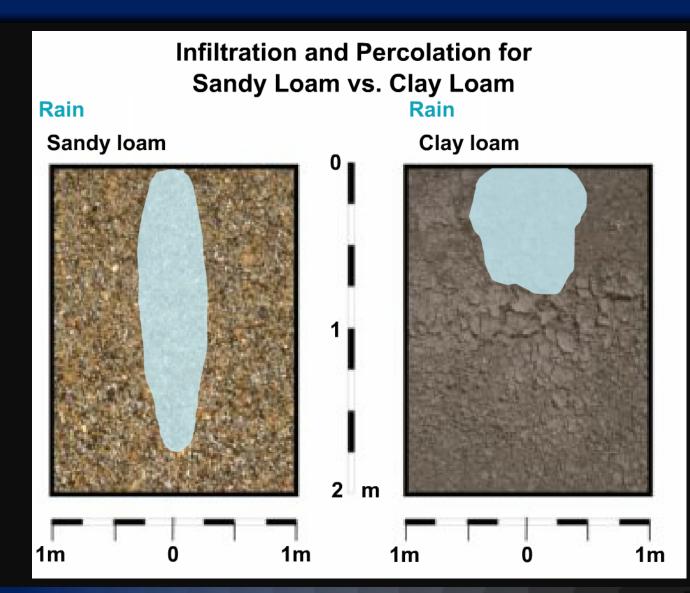
#### Pre-event assessment

#### Questions to ask / items to check:

- Is the ground/soil wet or dry?
- What type of soil exists? (sandy, clay, frozen)
- Are streams at baseflow or elevated?
- What is the topography of the area?
- More questions based on time of year
  - Have the trees leafed out yet?
  - Is there snow on the ground? Will the snow melt?
  - Could plowed snow or fallen leaves clog drainage systems?

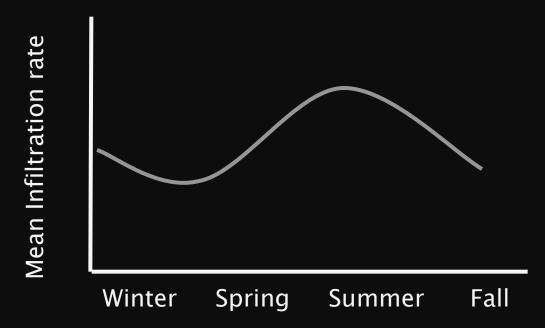
# **Soil Type Effects**

Sandy soils accept rainwater deeper into the ground faster, thus taking longer to approach saturation and leading to less flood susceptibility.



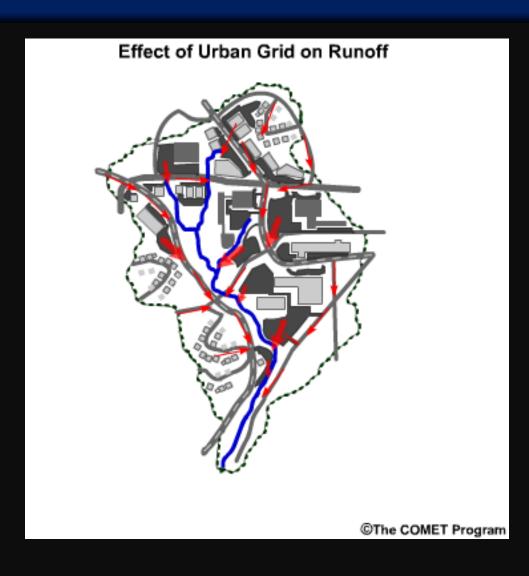
#### Soils

But also: Soil infiltration rate changes with the season.
This impacts flood potential!



### **How Urbanization Effects Flooding**

- Anything that cannot be absorbed into the soil becomes runoff.
- In an urban area, where surfaces like concrete and asphalt are impermeable, everything becomes runoff!



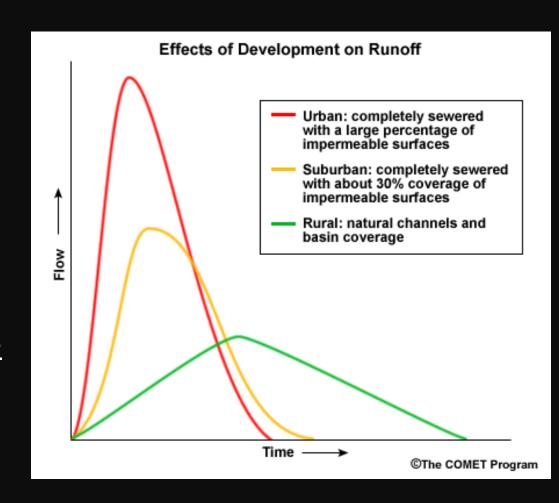
### Bigger, Faster, Better?

#### ▶ The good:

The stream reacts
 faster, and thus may
 be less susceptible to
 a prolonged event.

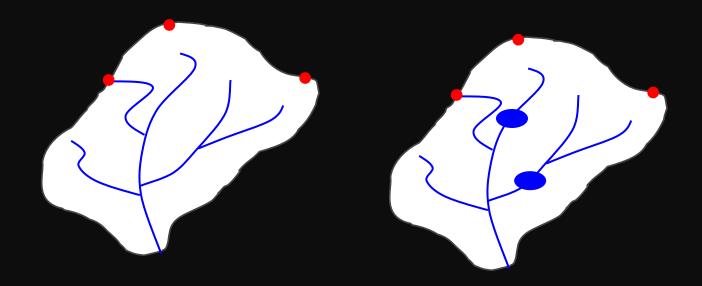
#### ▶ The bad:

The stream rises
 higher due to runoff,
 and thus may be more
 susceptible to a high
 intensity (but
 relatively short
 duration) event.



# Why Dams Can Be Helpful

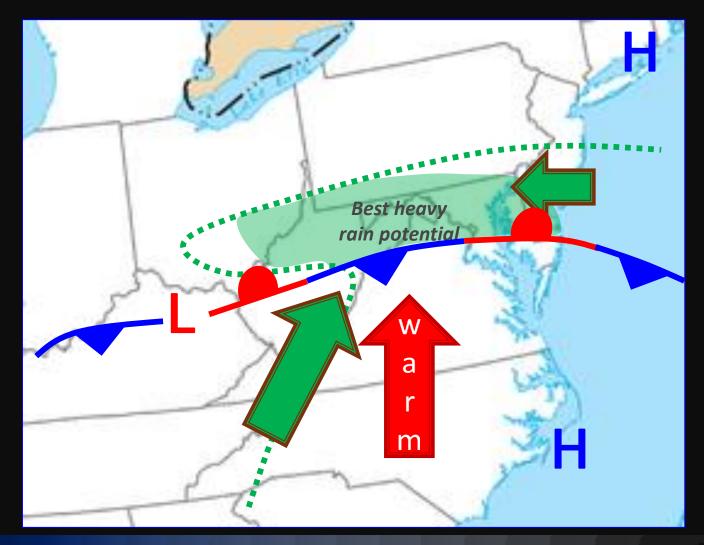
Key point: Lakes and flood control basins are important to locate



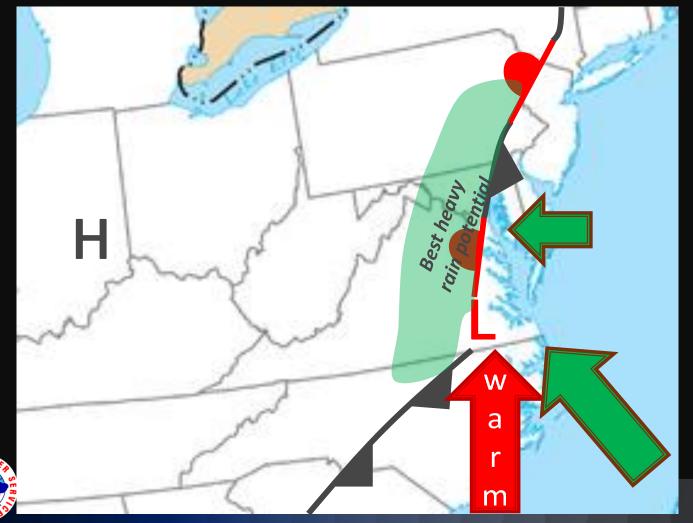
# Why Dams Can Be Harmful

Although it's rare, sometimes (due to a variety of factors) a dam could fail. If it does, downstream flooding can be catastrophic.

Slowmoving or Stationary Fronts

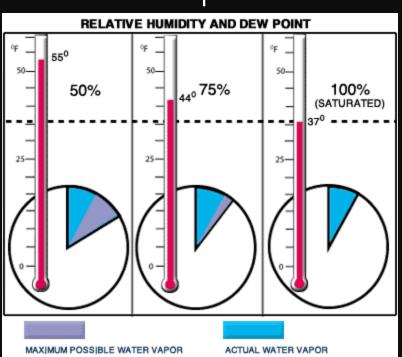


► Slow-moving or Stationary Fronts (this could also be the sea breeze!)

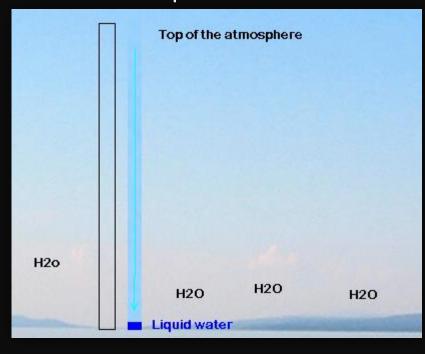


High Moisture Content

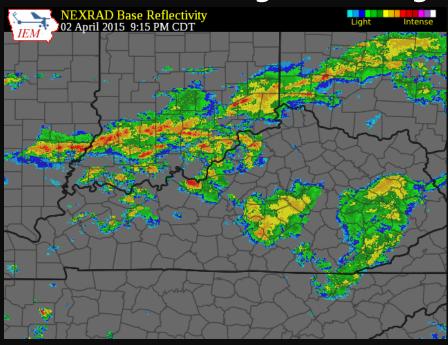
#### Dewpoint

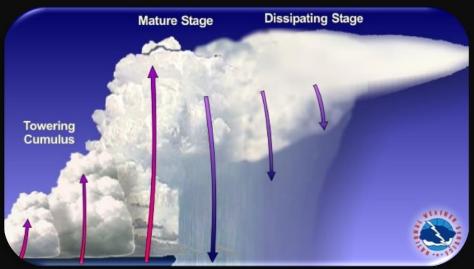


#### Precipitable Water



Slow-moving & Training (Repeating) Thunderstorms

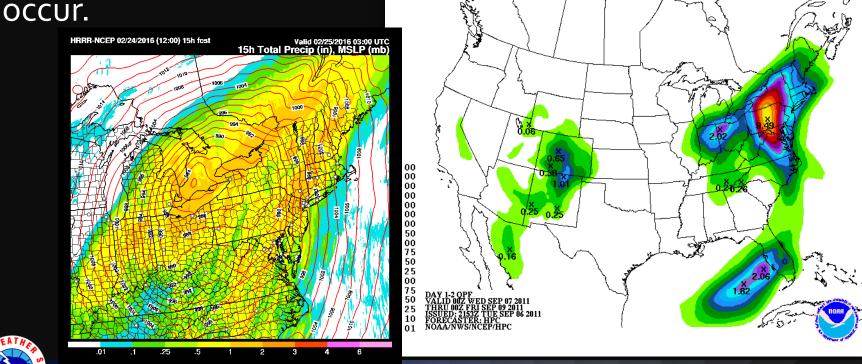




# Making a Rainfall Forecast

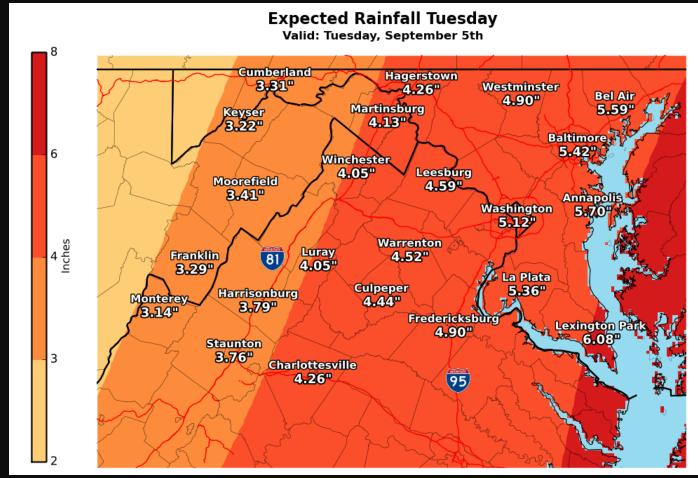
We begin with national precipitation forecasts from the NWS Weather Prediction Center (WPC).

▶ We then localize this — especially in the first 6-12 hours as we get the best idea of where the heaviest rain will



#### It's Not Just One Number!

If you see a graphic like this, and think we're this good...we're not.



# Putting It All Together

Once we have forecast an expectted amount <u>and</u> <u>range</u> of rainfall expected...we have to combine this forecast with the antecedent conditions, as well as <u>how quickly</u> the rain is expected to fall.



#### Flood vs. Flash Flood

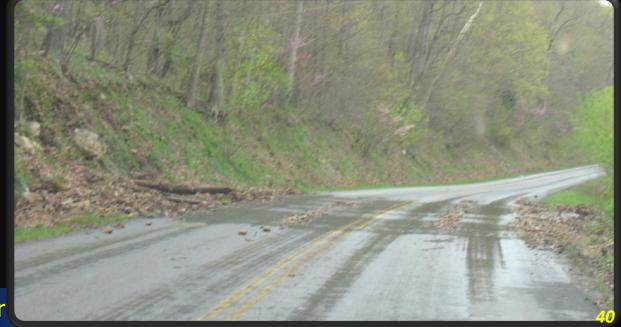
- ▶ Flash Flood a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). However, the actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters.
- Flood any high flow, overflow, or inundation by water which causes or threatens damage.

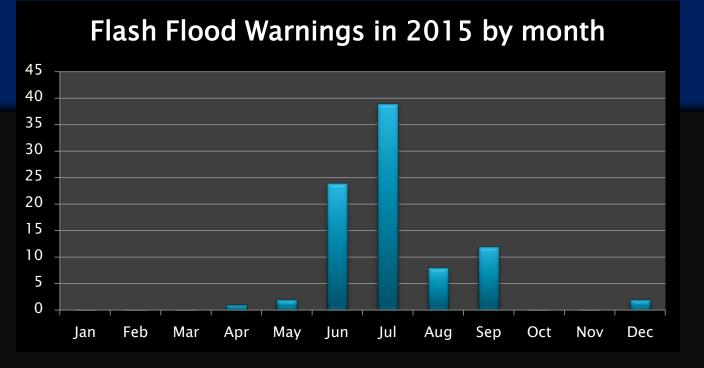
Source: NWS Instruction 10-950 dated December 4, 2012

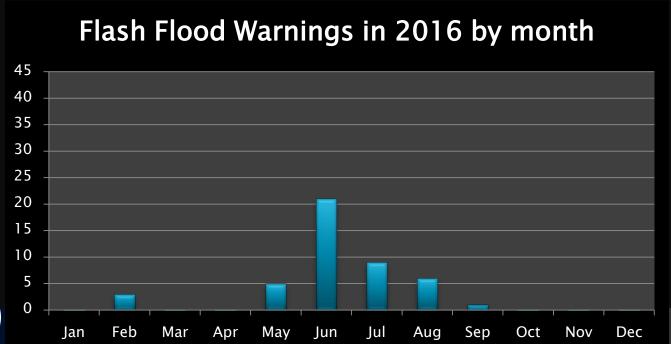
#### What makes a flash flood?

- Typical Flash Flood Characteristics
  - Caused by convection (thunderstorms or intense showers)
  - More isolated compared to flooding
  - Response time is short, usually 1-2 hours, but as little as 15 mins. in urban areas (compared to 6-12 hours for flooding)
  - Swift Water Rescues, road closures (especially major roads), creeks and streams flood within an hour or two of the
    - causative event
  - Occurs more frequently in urban areas and in terrain

Overland flow debris near Front Royal, VA – 2011









# When does flash flooding occur?

Can occur anytime – day or night.

Approximately two-thirds of all flash flooding occurs

at night.

Most flash flood fatalities occur at night!

Flash Flooding is NOT restricted to only mountainous areas.



# Location, Location, Location!

- Creeks
- Streams
- Ravines
- Washes
- Gullies
- Urbanized areas
- Underpasses
- Poor Drainage Areas



# Flash Floods – What to Report

- River or stream flows out of banks and is a threat to life or property.
- Person or vehicle swept away by flowing water from runoff that inundates adjacent grounds.
- A maintained county or state road closed by high water.
- Approximately six inches or more of flowing water over a road or bridge.
  - This includes low water crossings in a heavy rain event that is more than localized (i.e., radar and observer reports indicate flooding in nearby locations) and poses a threat to life or property.

See water where it doesn't belong, but it doesn't meet these criteria? Report it anyway, but <u>please</u> don't call it a flood! Be as descriptive as you can when you report.



# Flash Floods – What to Report

- Dam break or ice jam release causes dangerous out of bank stream flows or inundates normally dry areas creating a hazard to life or property.
- Any amount of water in contact, flowing into or causing damage of an above ground residence or public building and is runoff from adjacent grounds.
- Three feet or more of ponded water that poses a threat to life or property.
- Mud or rock slide caused by rainfall (could possibly occur in a burned area with only light-moderate rainfall).

See water where it doesn't belong, but it doesn't meet these criteria? Report it anyway, but <u>please</u> don't call it a flood! Be as descriptive as you can when you report.



# Special Cases – Debris Jams

- Occasionally, floating debris or ice can accumulate at a natural or man-made obstruction and restrict the flow of water.
- Water held back by the ice jam or debris dam can cause flooding upstream.
- Subsequent flash flooding can occur downstream if the obstruction should suddenly release.



# Special Cases – Ice Jams





Chunks of ice collect in river channels and may ultimately stop the flow of water.

Ice can collect at a bridge and create an ice jam.

Water backs up behind the ice jam and subsequent flooding results.



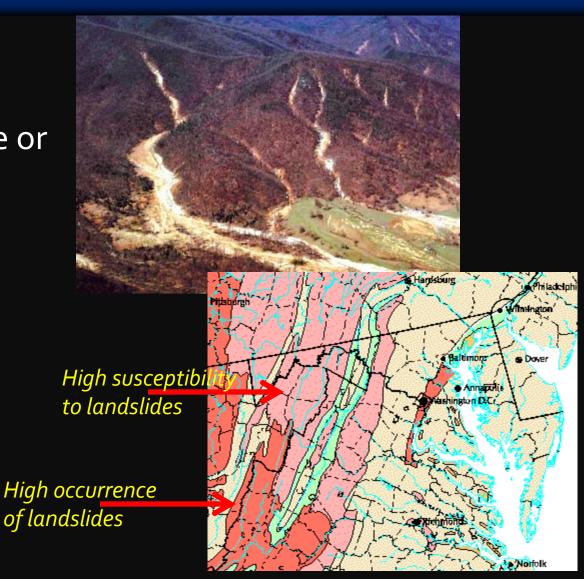


# Special Cases – Ice Jams



### Special Cases – Mudslides/Landslides

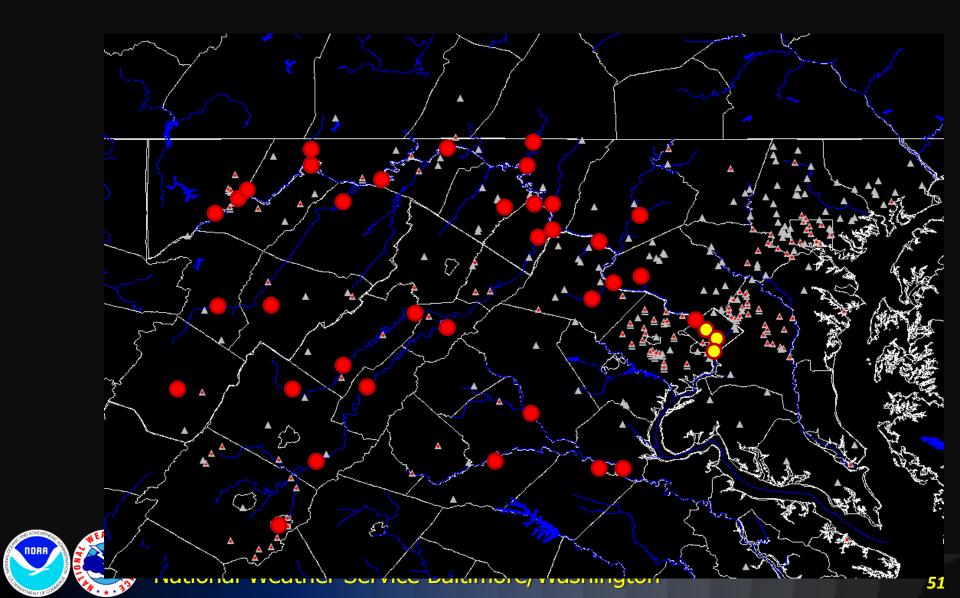
- In significant rain events in higher terrain, a mudslide or landslide can be triggered.
- This isn't the rain rushing down the slope; it's the <u>land</u> rushing down the slope.



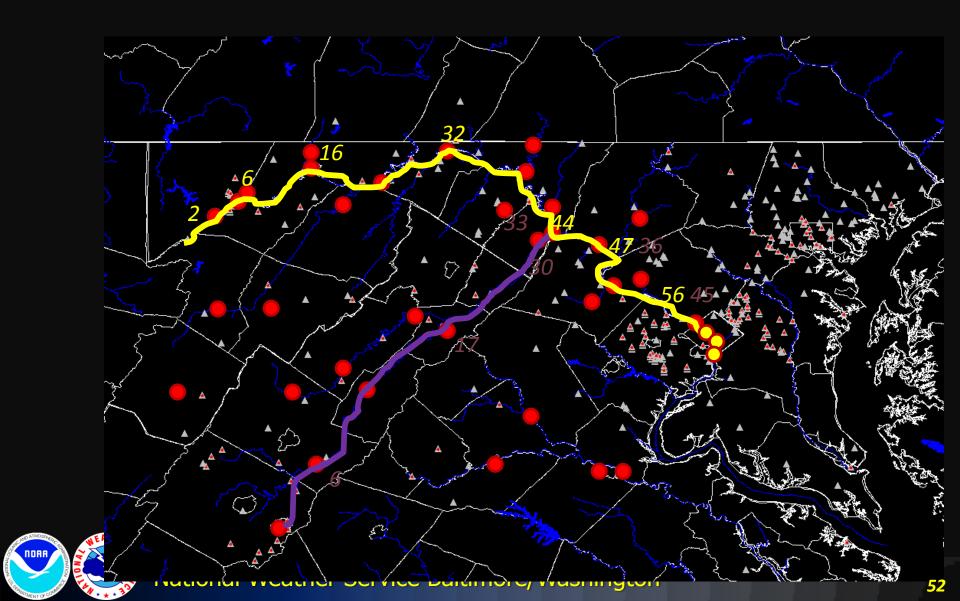
#### What's this "Areal" Flood?

- NOT = "a real" flood
- NOT = "aerial" flood
- Flooding that covers an area.
- Flash Flooding typically affects a *very* small area. Areal flooding is slower to develop (usually > 6 hours) and usually affects a larger area.
- But...other than the time constraint, the "what to report" is exactly the same.
  - (We'll go over it again in the second half of the presentation.)

# **River Flood Forecast Points**



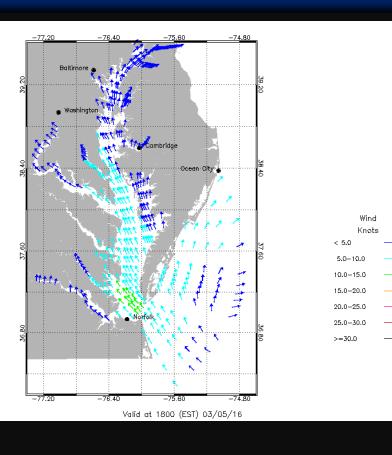
# Travel Times (in hours)



# **Coastal Flooding**

- Prolonged onshore flow
- Storm Surge from Tropical Systems







# **Coastal Flooding**

- Two distinct peaks for positive departures

  April/May & September/October
- September stands out due to tropical systems

Minor Coastal Flooding at the US Naval Academy June 2005





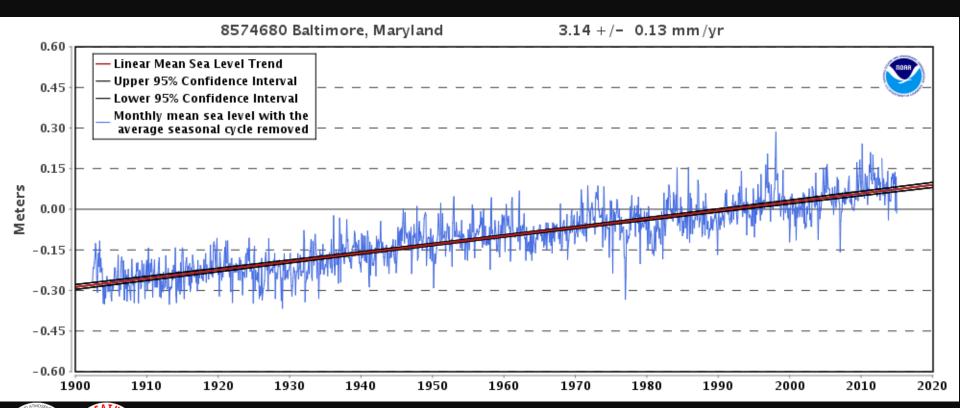
# **Coastal Flooding**





#### On the Rise

Mean Sea Level (MSL) is steadily rising... (average rate ~1 foot/century)





#### More of a Nuisance

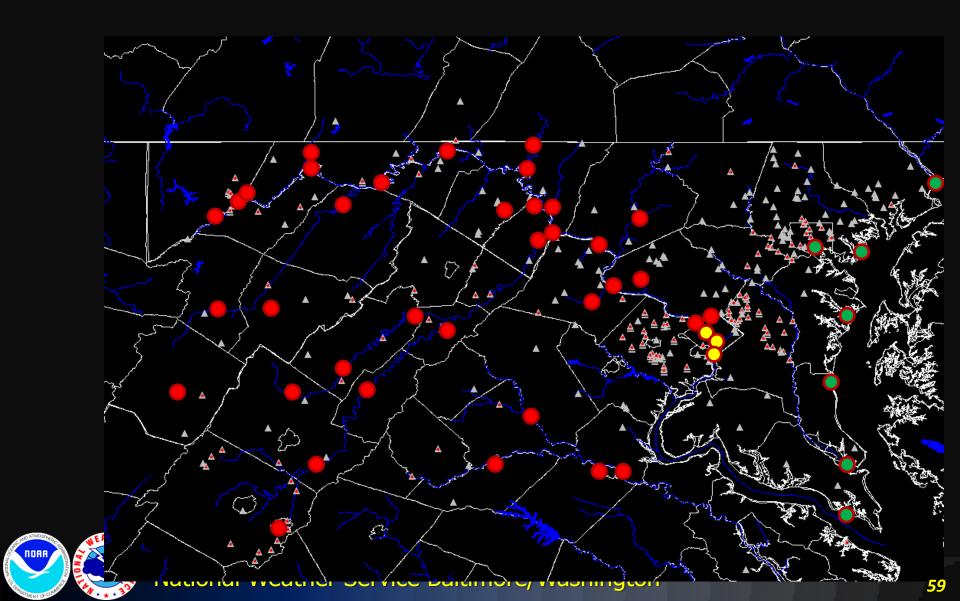
- A NOAA study finds that nuisance flooding (defined as reaching our NWS 'minor flood' level) has substantially increased in the last 50 years.
  - This is due to a rise in the base water level, not due to increased storms.

City	Average nuisance flood days (1957-63)	Average nuisance flood days (2007-13)	Percent increase
Annapolis	3.8	39.3	925%
Baltimore	1.3	13.1	922%
Washington	6.3	29.7	373%

### Weather Plays a Role

- During strong El Niño patterns, there was a much higher incidence of days with storm surge > 1 foot, and higher mean sea level along the Mid-Atlantic Coast.
  - Sweet and Zervas (2011)
- Recent years with stronger El Niño:
  - ° 2015-2016 (2.3)
  - Late 2009 Early 2010 (1.6)
  - 1997 Early 1998 (2.3)
  - 1991 1992 (1.6)
  - 1982 1983 (2.1)
  - 1972 Early 1973 (2.0)

# **Flood Forecast Points**



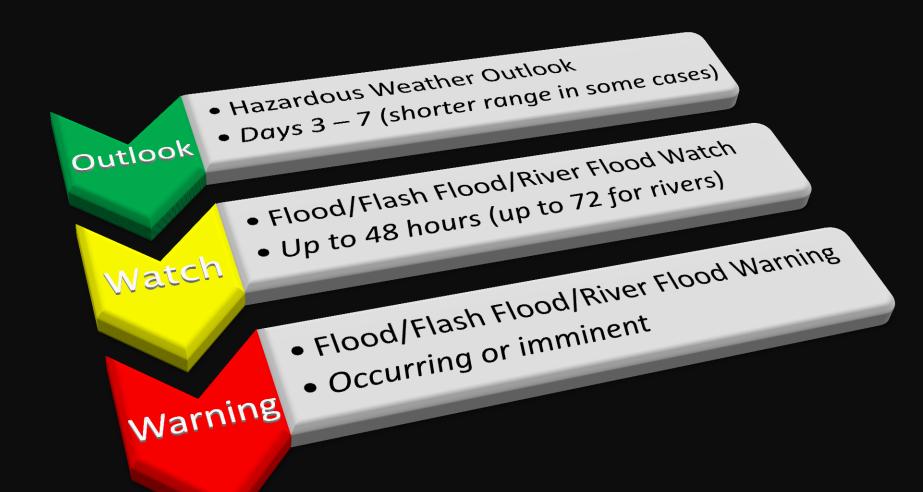
# Flood Type Summary

- In a single event, we must consider:
  - Flash Flooding
  - Areal Flooding
  - Nuisance Flooding
  - Tidal Flooding
- ...often all at the same time...and at the same time as severe weather or other hazardous weather...
- ...and ensure the public is properly notified of any/all of these threats that may affect them!

### As a spotter...

- Don't worry about characterizing the <u>type</u> of flooding. Just give the facts, as specifically as possible, and we can do the characterization.
  - More on that in a little bit!

# **Our Products**





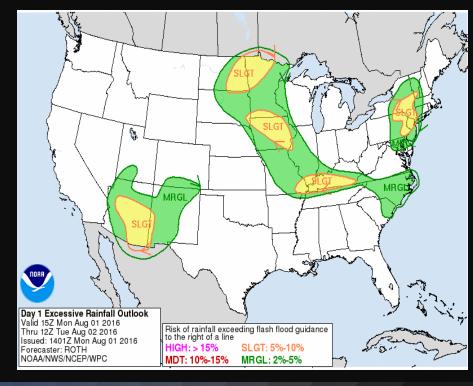
#### **Outlook Phase**

- The Hazardous Weather Outlook will mention:
  - Flood potential in the Day 3-7 period
  - Flood potential in the first 48-72 hours, if confidence is too low for a watch

Coastal flood potential for <u>moderate flooding or greater only</u> at any

time in the seven day forecast.

The Weather Prediction Center (WPC) issues Excessive Rainfall Outlooks for Days 1-3. These are not a direct indication of flood potential, but can be useful for confidence.



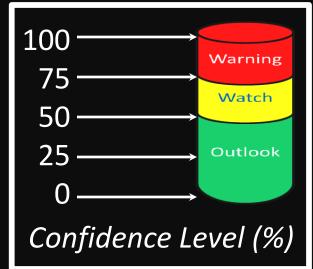


### Watch vs. Warning

WATCH: Conditions are favorable for flooding to occur (>50% chance). Be alert for possible flooding during the watch period.

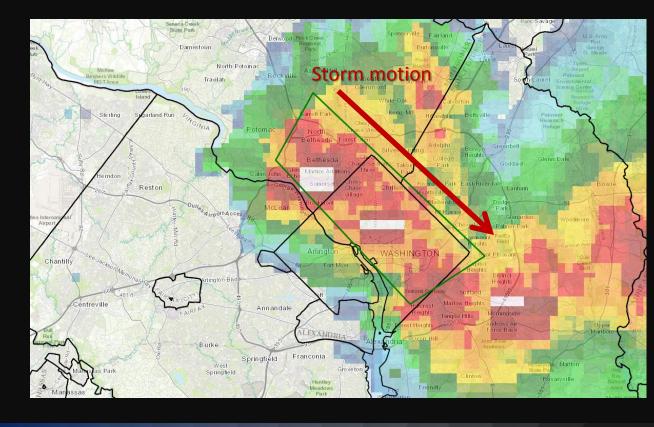
WARNING: Flooding is occurring or is extremely likely to occur (>75% chance). Stay out of low areas and seek higher ground if necessary!

Note: A watch does not necessarily precede a warning, especially for river flooding.



### **Basin-Based Warnings**

- Our goal is to warn for:
  - Where the rain is going to go
  - Where the water is going to flow
- This means we may warn for places where it will not even rain!



### Respect the Polygon!

- All flood warnings (except coastal flood) are issued as polygons.
  - Limits the area covered by a watch or warning
  - If you're not in the box, we believe your threat is low!
- For watches, <u>only</u> river flood watches are issued as polygons.



Reminder: While all areas in the polygon are perceived to have an imminent flood threat, in most cases only a few small areas will actually experience flooding.

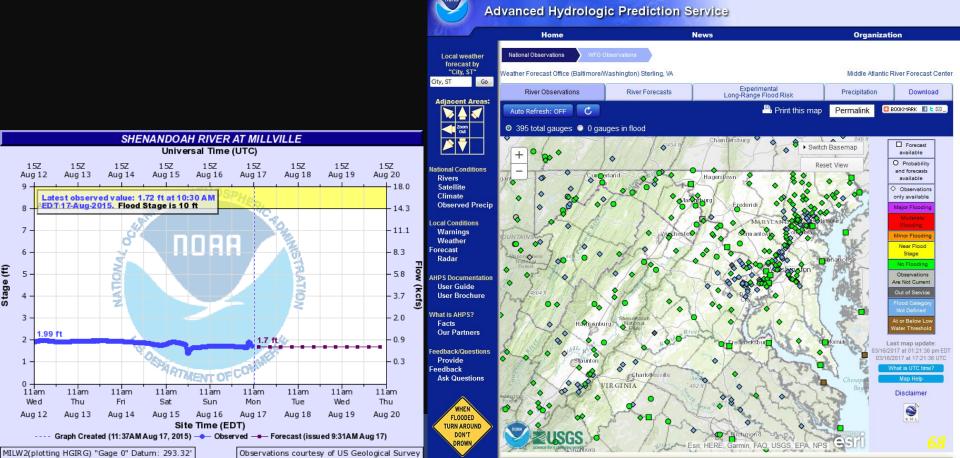
#### Where does it flood most often?

- Cacapon River near Great Cacapon, WV (GCPW2) 2.3x / year
  - Morgan County
- ▶ Opequon Creek near Martinsburg, WV (MBGW2) 2.1x / year
  - Berkeley & Jefferson Counties
- ▶ Robinson River near Locust Dale, VA (LOCV2) 1.8x / year
  - Madison & Culpeper Counties
- Western Branch at Upper Marlboro, MD (UPRM2) 1.7x / year
  - Prince George's County
- Whitemarsh Run at White Marsh, MD (WHMM2) − 1.7x / year
  - Baltimore County
- ▶ Shenandoah River near Millville, WV (MILW2) 1.6x / year
  - Jefferson & Clarke Counties
- Mechums River near White Hall, VA (MECV2) 1.5x / year
  - Albemarle County
- ▶ Seneca Creek at Dawsonville, MD (DAWM2) 1.5x / year
  - Montgomery County
- Otter Point Creek at Edgewood, MD (EDGM2) 1.5x / year
  - Harford County
- St. Mary's River at Great Mills, MD (GMRM2) − 1.4x / year
  - St. Mary's County
- ► Monocacy River at Bridgeport, MD (BDGM2) 1.4x / year
  - Frederick County MD



# Viewing live river data & forecasts

http://water.weather.gov



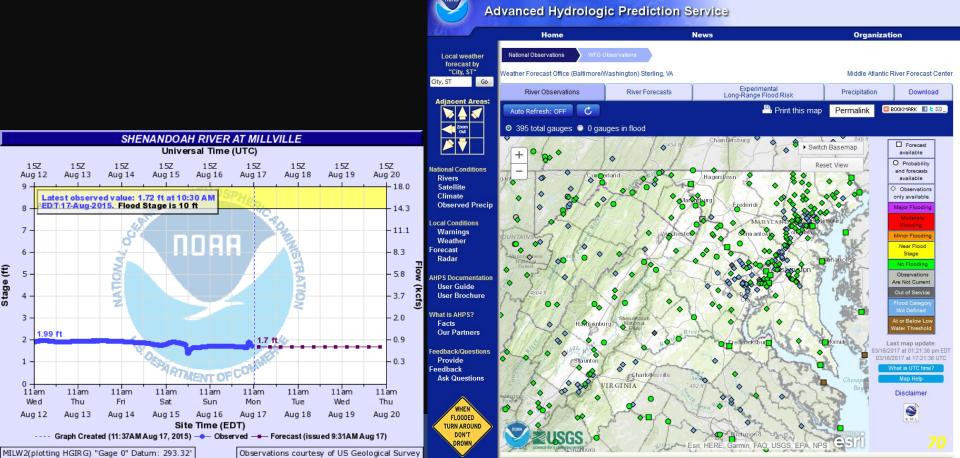
**National Weather Service** 

#### **Break time!**

# Please return in 5 minutes

# Viewing live river data & forecasts

http://water.weather.gov



**National Weather Service** 

# Observations during heavy rain

- Ground truth
  - Nothing ever beats an eye in the field!
  - Rainfall measurement / flood report / stream measurement
    - Safety is always key!

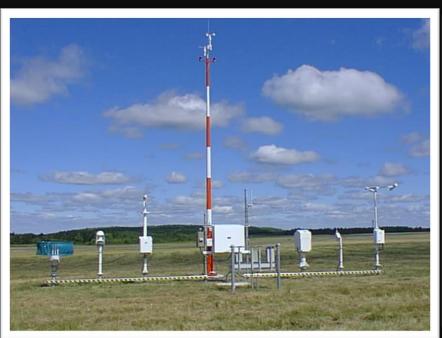


US 301 / MD 4 Prince George's Co., MD



# Observations during heavy rain

- Automated observations
  - Near-real time, but...
    - Subject to error/clogging/freezing
    - No measurement of how much of the fallen rain is being soaked into the ground, and how much is running into streams

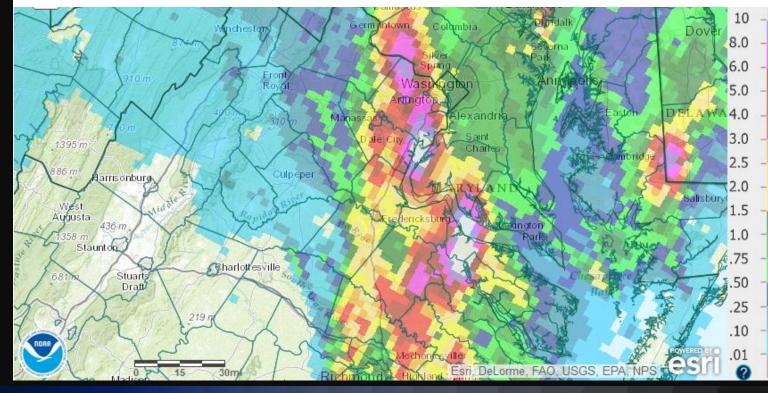




#### **Precipitation Estimates**

- Remote Sensing
  - Radar
  - Satellite

Baltimore/Washington, VA (LWX): 9/9/2011 1-Day Observed Precipitation Valid at 9/9/2011 1200 UTC- Created 9/11/11 23:31 UTC





#### The "Ultimate Combo"

- Ground truth observations
- Radar & satellite estimates skewed by ground truth
- Gaps filled in by radar & satellite
- Spotter reports are vital!
  - Rain amounts
  - River level status
  - Is there water over the road?
    - (We'll talk more about this later...)

**Ellicott City, MD** 







# Why Do We Need Spotters?

- ▶ All one team!
  - **Emergency Managers**
  - Other Government Agencies
  - **Broadcast and Print Media**
  - **SKYWARN Spotters**
  - Amateur Radio Operators

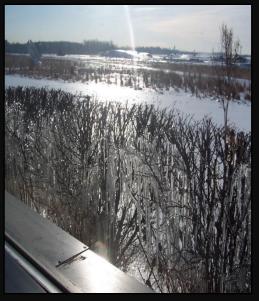


#### **Spotter Reports**

#### Answer the 4 Ws:

- Who are you?
- What is your report?
- When did this happen?
- Where did this happen?





#### Tips:

Give us your spotter number & name
Be descriptive about what you see
(pictures are great, but be safe!)
Be as specific about location as possible



# Why Specificity Matters

Floods are not created equal!



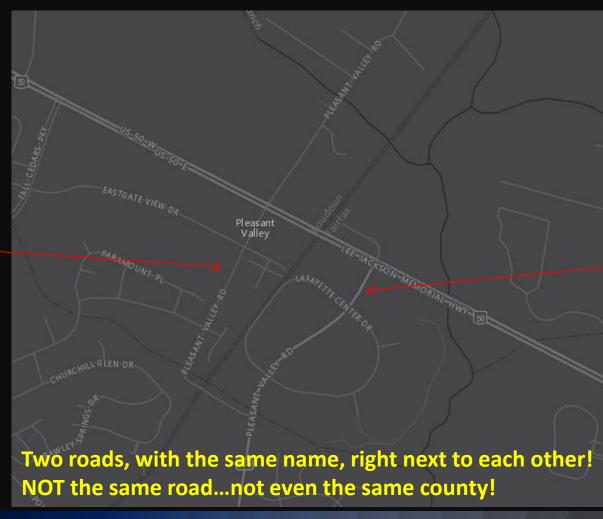
VS.



# Why Specificity Matters

Location...location...location!

Pleasant Valley Rd (Loudoun Co.)



Pleasant Valley Rd (Fairfax Co.)



### What to Report

- Heavy Rain measured 1" or more (we prefer to get periodic reports & a storm total at end)
- Rainfall Rate –
   Rainfall in inches per hour
   (Warning: automated weather)

stations often provide an "instantaneous rain rate" which can sometimes be 10+ in/hr...this is <u>not</u> what we are looking for!)



### What to Report

Flooding & Flash Flooding – Streams, creeks or rivers out of banks or flooding of roads

#### **Things to look for:**

- Is the water still or flowing?
- How deep is the water?
- What is the source of the water? (stream? drainage ditch? poor drainage?)
- If a road is impacted, lat/lon or block #
- Are any structures impacted (including outbuildings)?
- Can you <u>safely</u> get any pictures?





### **Terminology Reminders**

#### By NWS Definition –

A flood/flash flood must impact life or property!

 Water over the banks of a stream but not affecting anything is technically not a flood...but we'd still like to know! Let us know that "(name of stream) is bankfull" or "just over bankfull".

#### Low Water Crossings –

We have many of these in this area. They are <u>designed</u> to be covered by water while the stream is entirely within its banks. (Not a flood!) If the "flood" is of a low water bridge, please say so!



### Flood Spotter Safety Reminder

▶ Don't become a statistic! Practice what we preach! → If you come across a flooded road, that <u>is</u> a report! Don't drive through it looking for more flooded roads!



### Winter Reports

- ► Ice Accretion Any glaze on surfaces (or more) →
- Snow Accumulation Every 2" and a storm total, or any accumulation not reflected in the forecast



Average Ice Accretion 5/16" = 0.3"



#### Bonus points ©:

Snow Water Equivalent – melt your snow down to see how much water is within it

**Snow Measurement Guidelines:** 

https://madis-data.noaa.gov/snow\_measurements.html



### Non-hydro spotter reports

Although we don't go into severe reports here, if you're already a spotter by having taken our Basic course, you certainly should report that too!



#### How to report

- Call NWS Sterling as soon as you see something: (800) 253-7091
- You can email delayed reports or pictures to:
  - LWX-Report@noaa.gov
- Contact local Emergency Management
- Amateur Radio (when activated)
- If you see signs of flooding after the event, let us know! Immediate reports are best; but no report is too late!
- If a report is second-hand (not directly from you), please let us know that.

#### Best way to report

#### **VERY IMPORTANT INFORMATION:**

- Please DO NOT send flooding reports by email, unless you see it after the fact, have a picture, or can't get to a phone!
- This is very time critical information that needs to be relayed to forecasters immediately.
- Best means to get information to the NWS quickly is via the telephone or Amateur Radio.
- Rainfall/snowfall observations via email/web form are fine unless you think we need to know more urgently.

#### PLEASE DON'T WAIT FOR US TO CALL YOU! (we will...)

### **Additional Reports**

# If you have a rain gauge or automated weather station:

We would love to have your reports <u>routinely!</u>

Rain gauge or automated weather station must be well-sited (not attached to side of house, not under

trees, etc.)







#### Five easy steps

Simply sign-up on the CoCoRaHS web page: www.cocorahs.org

Obtain a 4" plastic rain gauge

View the on-line "training slide show"

Set-up the gauge in a "good" location in your yard

Start observing precipitation and report on-line daily



#### Flood History

#### Did you know?

#### The first recorded floods in this region were in 1748!

- A teenaged George Washington, working as a land surveyor, could not cross the Potomac River at Berkeley Springs due to flooding from snowmelt. Washington instead spent time at the "Medicinal Springs" (today's Berkeley Springs).
- As the flood (maybe the same one, we're not sure) moved down the Potomac, Robert Harper – the namesake of Harpers Ferry – had to leave his log cabin and move into a barn up on the hill.

http://www.weather.gov/washington/FloodTimeline

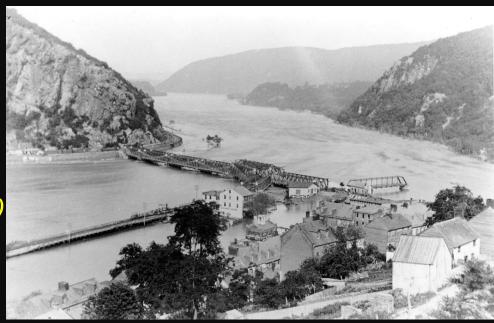
#### Flood History

- Then the hits just kept on coming...
  - 1810 Record Flood
  - 1845 Year of the Floods (three: April, and two in September)
  - 1852 Record Flood
  - 1870
  - 1877
  - · 1889
  - 1896
  - ...and on...and on...

# September 30 – October 1, 1896

- Twenty-sixth anniversary (to the day) of another major flood in 1870
- Caused by a tropical storm / hurricane
- Rivaled the 1889 flood in Harpers Ferry

Flood of June 1, 1889 in Harpers Ferry.
The Bollman Bridge across the
Potomac River survived the flood, but
the Shenandoah wagon bridge was
swept away. John Brown's Fort is all
that's left of the old Armory.
(Photo courtesy David T. Gilbert; from
the Historic Photo Collection of
Harpers Ferry National Historical Park)



### March 17-19, 1936

- Still, to this day, the record flood on the Potomac.
  - The record flood on the Shenandoah is 1942



# November 1985 "Election Day"

- Significant flood on the Potomac
  - Flood of record on SB Potomac and headwaters of Shenandoah



# January 1996

- Last significant snowmelt flood in our area
  - Flood of record in Cumberland, MD on Wills Creek



# September 1996 – "Fran"

- Last significant Potomac River flood
  - Flood of record on much of the Shenandoah



#### June 2006 Flash Flood

- Significant flood for Washington DC
  - Major damage elsewhere, mainly in metro areas



Flooding of Constitution Avenue in DC Photo courtesy GSA



#### What Causes Floods Here?

- Stalled fronts in the winter & spring
- Summertime storms
- Tropical storms / hurricanes
- Snowmelt
- Unusually high tides (sometimes not from hurricanes)

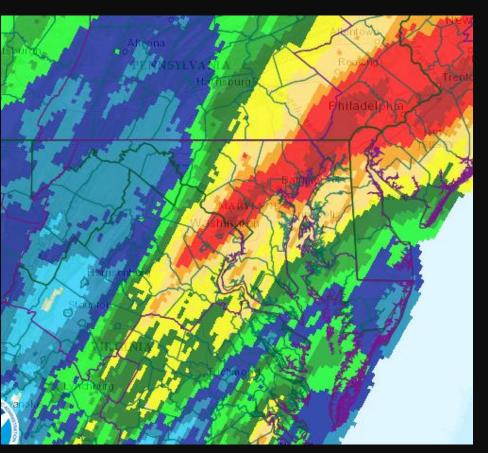
Now let's look at cases of these in more detail...

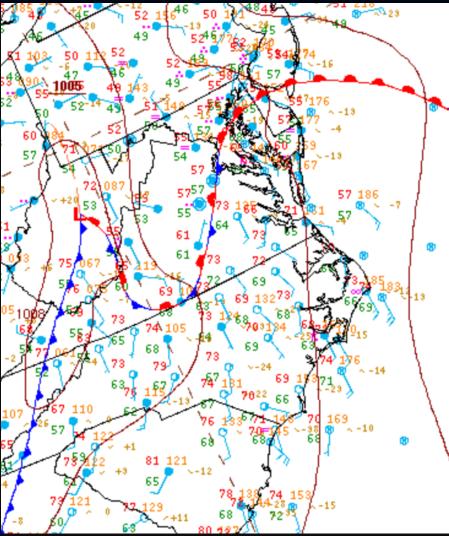
#### Stalled Fronts

- April 30, 2014
  - DC & Baltimore Metro Areas
- June 10, 2014
  - College Park and Clear Spring, MD

# April 30, 2014

▶ Does this look familiar? →









# April 30, 2014

Widespread flooding and flood warnings



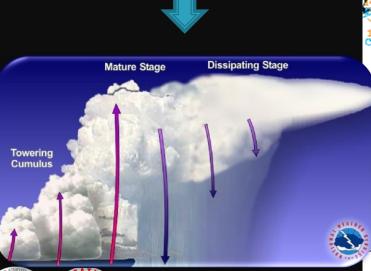
Clara Barton Parkway in Maryland Photo from J'aime Kirlew

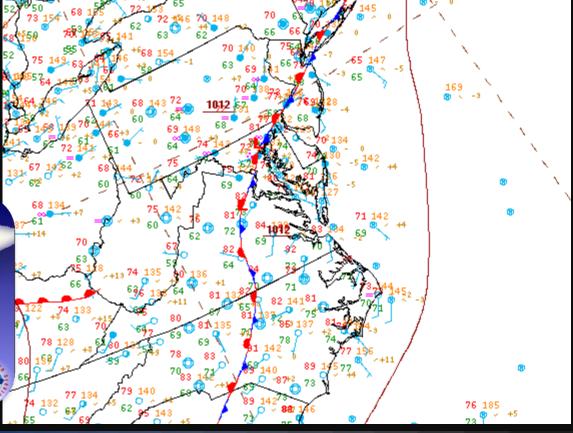


...also coastal flooding

#### June 10, 2014

- Not as typical of a case as the last one:
  - Stalled front in June?
  - Storms formed in the morning
  - And did this...



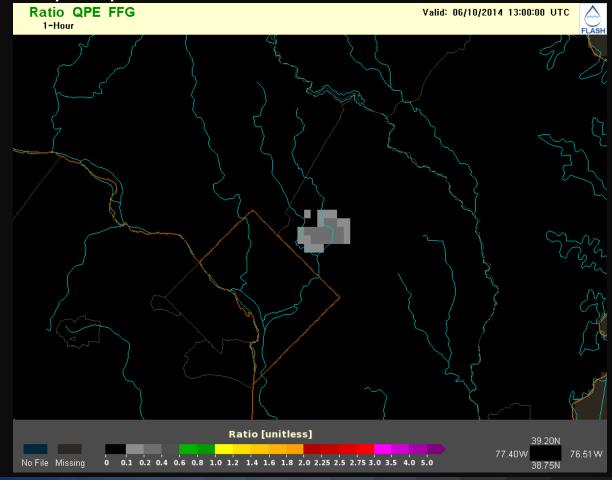


### College Park Flood – 6/10/2014

Our goal is to provide a one-hour advance notice of a flash flood. Sometimes this is literally impossible.

\* Image is from 9am

\* Flooding began by 9:57am, with water rescues before 10:00am.

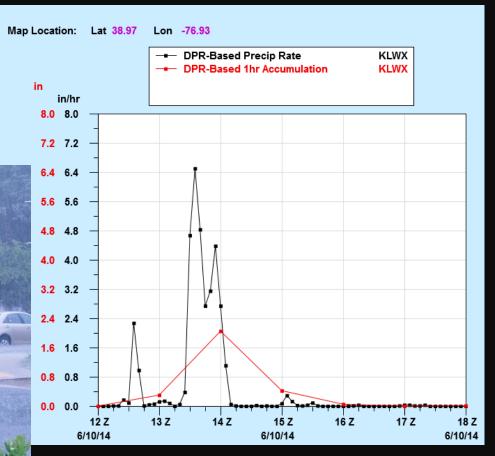




### College Park Flood – 6/10/2014

That 20-30% on the last slide was from a <u>previous shower!</u>

Really, it didn't even begin raining hard until 9:30am!



East-West Highway in Riverdale, MD *Photo from Anand Parikh* 

#### **Summertime Storms**

- June 27, 1995
  - Madison County, VA
- June 12, 2014
  - College Park and Clear Spring, MD
- July 30, 2016
  - Ellicott City, MD

#### June 27, 1995

- Affected foothills of central Virginia
- ▶ 24" rain within 24 hours
- 3 fatalities
- Mud/Debris slides
- All bridges in and out of Madison County were washed out or damaged except for U.S. Route 29 South.



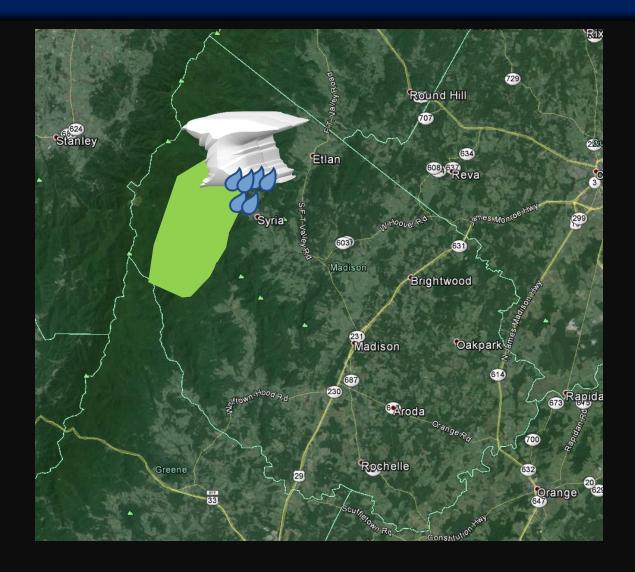
Rt. 29 @ Madison/Greene County Line



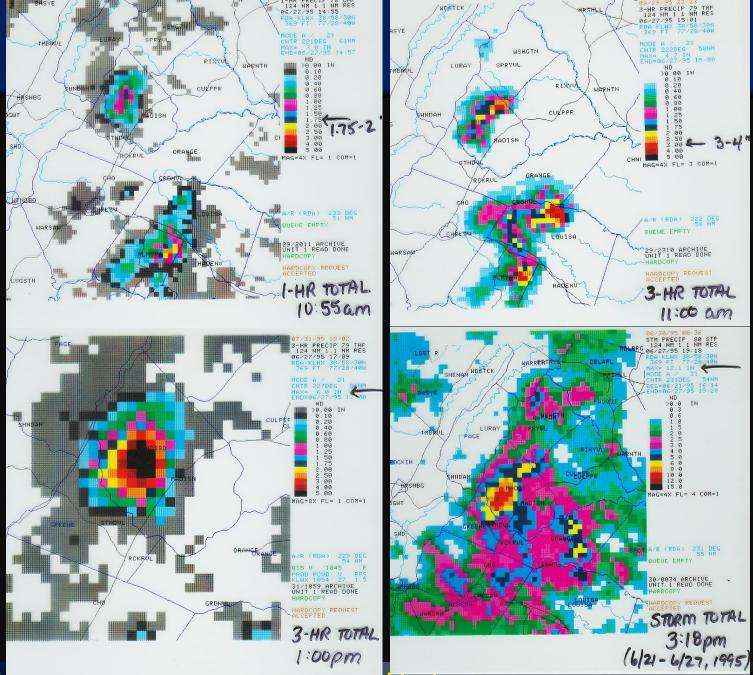
Rapidan River poured over U.S. Rt 29 at the border of Madison & Greene counties



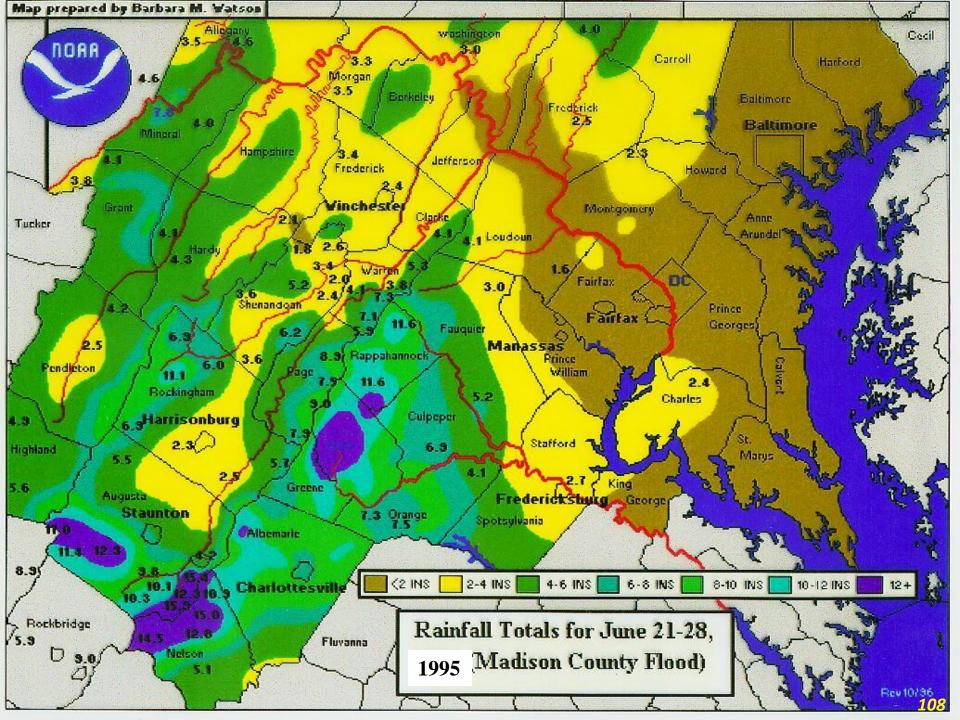
#### **How it Happened**



#### Rain

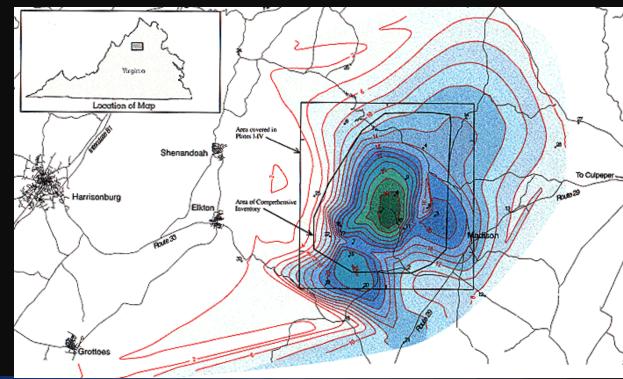






#### Madison County (VA) Flash Flood

- Precipitable water before the event from the Dulles sounding was 1.97", near record high for the date.
- ▶ The Rapidan River was flowing at <u>125 times</u> its normal rate 37 *billion* gallons per hour!
- Rainfall of 20 to 30 inches over quite a large area



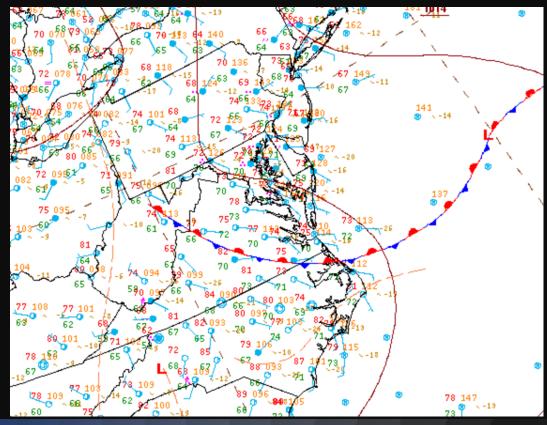
## Madison County (VA) Flash Flood

- Radar was underestimating rainfall - ratio of ground truth to radar estimates was 1.8:1.
- As flooding became more severe, communications were lost.
- Skywarn amateur radio spotters provided the first ground-truth report from Madison County.
- At 2PM, Etlan reported 10", with 5" falling between 10AM & 2PM.
- Record Flooding along the Rapidan River near Ruckersville and Culpeper

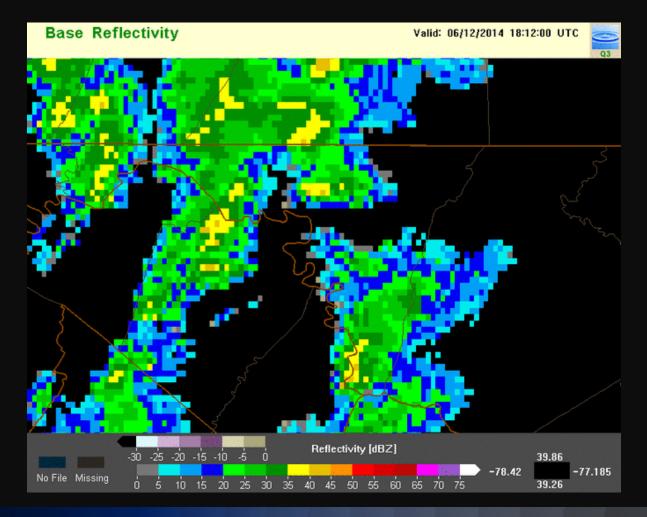


#### June 12, 2014 – Clear Spring, MD

- You might have noticed...this is only two days after the College Park event we just talked about.
- ▶ The stalled front...gone.
- ▶ Deep easterly flow off the Atlantic →
- Typical afternoon& evening storms

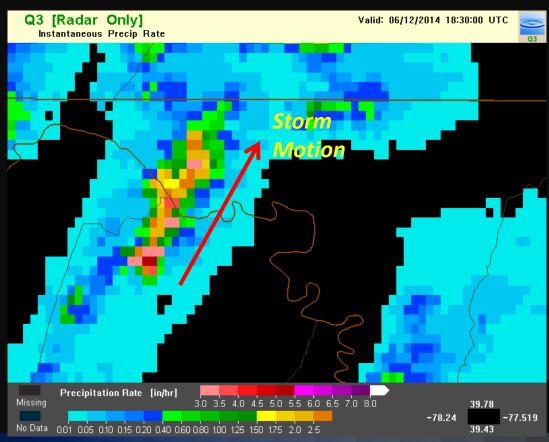


▶ Radar Base Reflectivity 1812 – 1900 UTC:



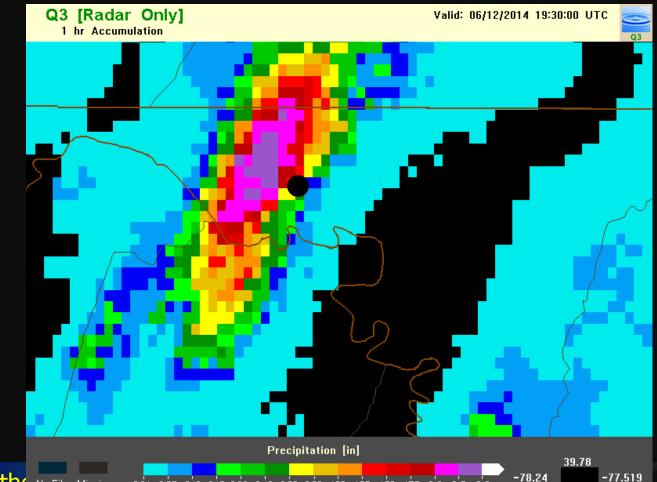


Instantaneous Rain Rate product at 1830 UTC:





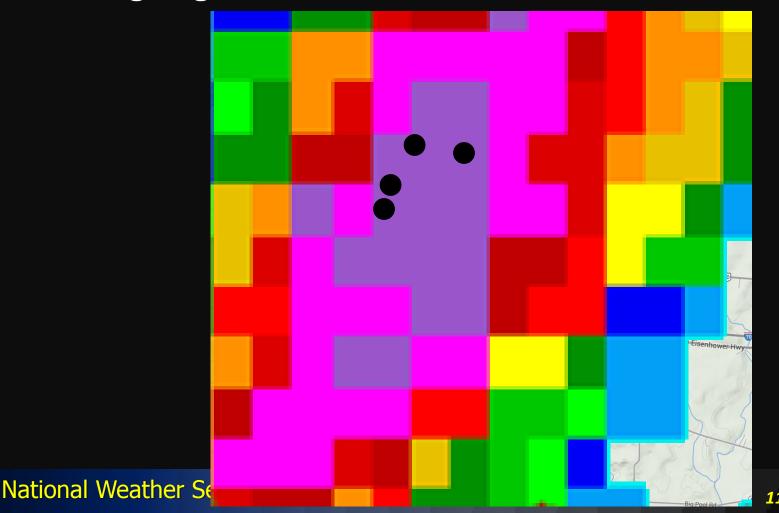
- One Hour Precip at 1930 UTC:
- Note where Clear Spring is!





National Weath ( No File Missing 0.01 0.05 0.10 0.15 0.20 0.40 0.60 0.80 1.00 1.25 1.50 1.75 2.0 2.5 3.0

▶ Always warn for where the rain's going to go <u>and</u> where the water is going to flow!





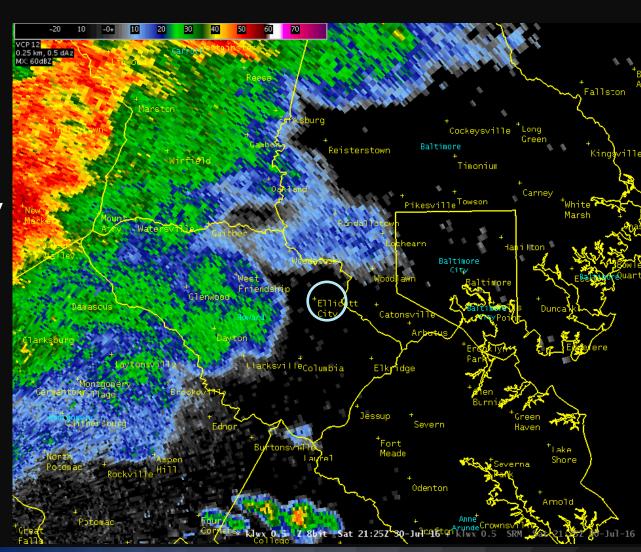


Flooding in Clear Spring, MD (photo from Hagerstown Herald-Mail)

## **Ellicott City Flood Overview**

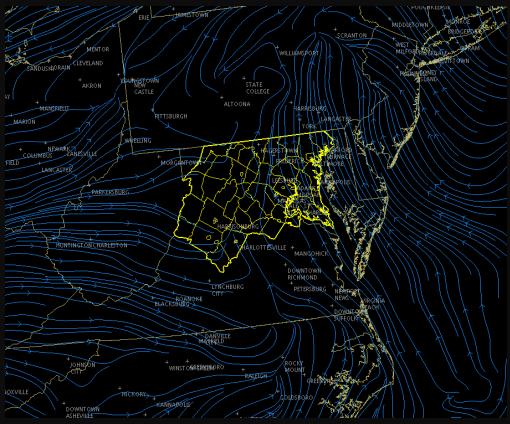
On the evening of July 30, 2016, heavy rain formed into a persistent band affecting a small multi-county area in central Maryland.

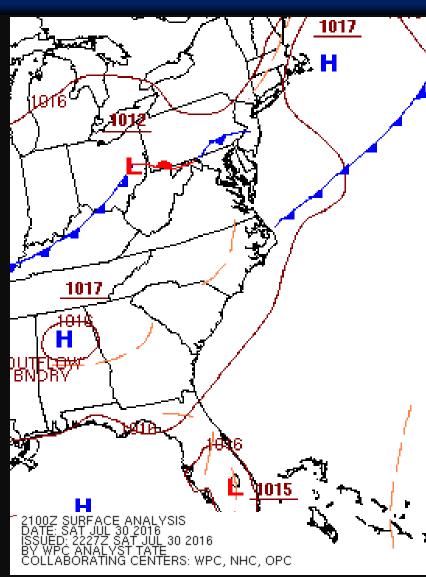
KLWX Radar loop from 2125 UTC 30 July to 0102 UTC 31 July



## **Synoptic Setup**

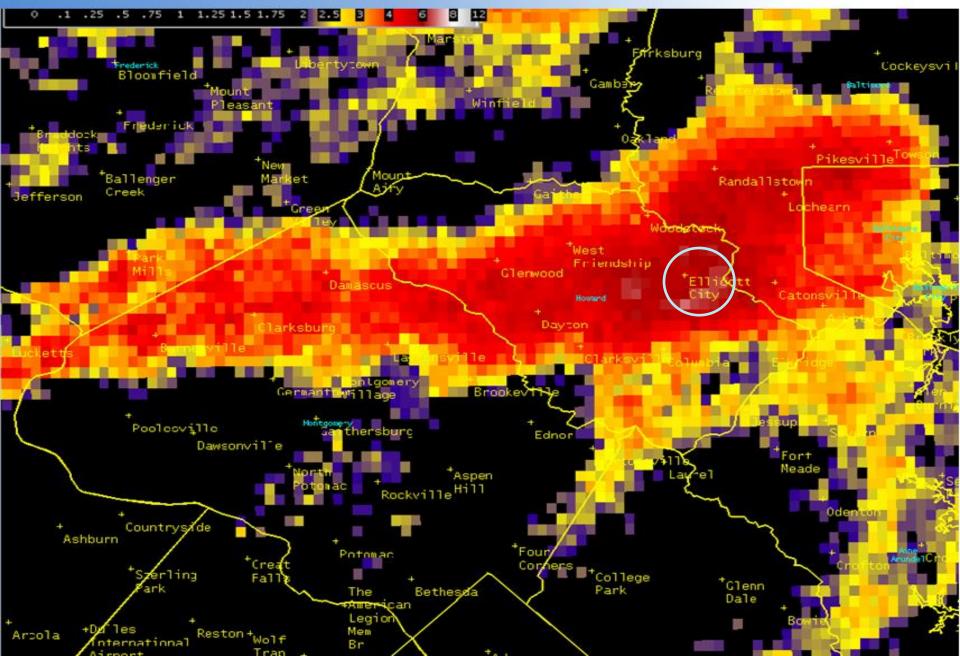
SFC boundary near Mason-Dixon Line Strong low-level inflow off Atlantic





#### Precipitation Estimates – July 30, 2016



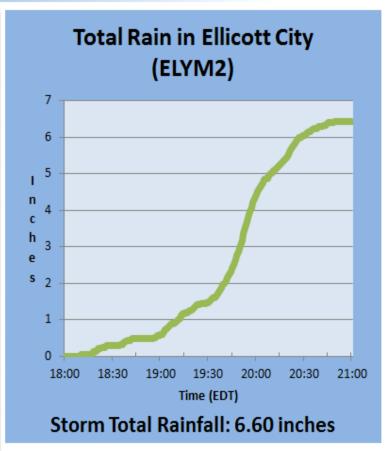


#### **Extreme Precipitation**

#### Historic Rainfall in Ellicott City, Maryland – July 30, 2016



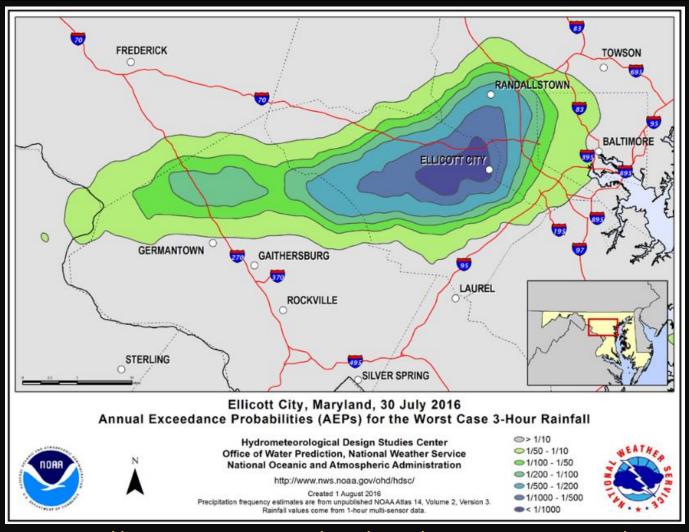
Duration	Max Rainfall in Duration	Time of Occurrence
1 minute	0.20"	7:52pm-7:53pm
5 minutes	0.80"	7:50pm-7:55pm
10 minutes	1.44"	7:50pm-8:00pm
15 minutes	2.04"	7:46pm-8:01pm
20 minutes	2.44"	7:44pm-8:04pm
30 minutes	3.20"	7:36pm-8:06pm
60 minutes	4.56"	7:30pm-8:30pm
90 minutes	5.48"	7:00pm-8:30pm
2 hours	5.96"	6:50pm-8:50pm



Information obtained from the Ellicott City (ELYM2) rain gauge.

This gauge reports in 0.04" increments.

#### **Precipitation Annual Exceedance**

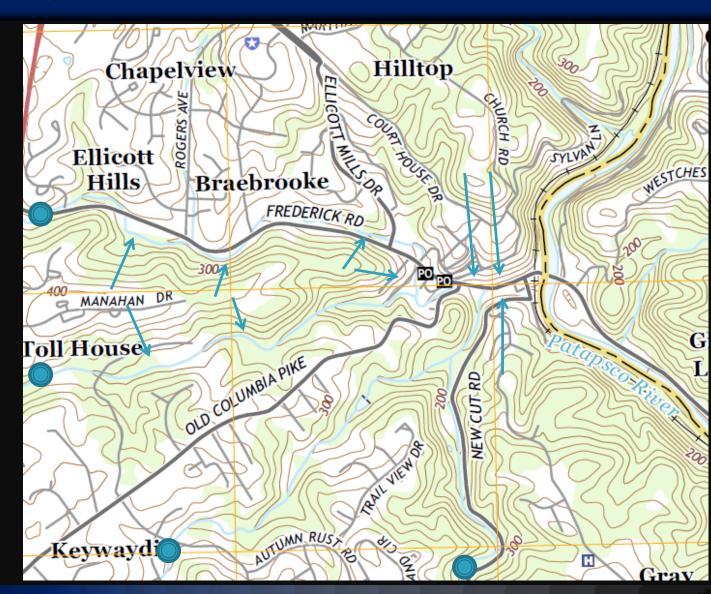




http://www.nws.noaa.gov/ohd/hdsc/aep\_storm\_analysis/

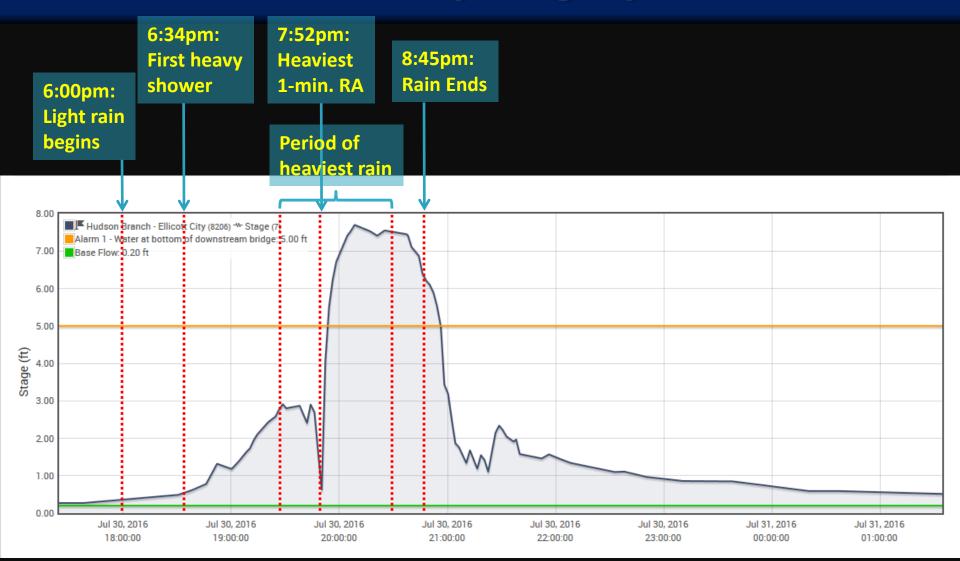
# Geography – Terrain & Streams

In addition to the four streams, local runoff can also occur off relatively steep terrain throughout the watershed.



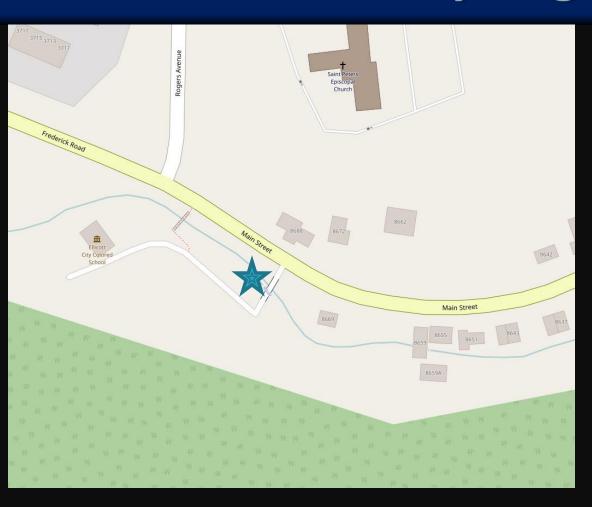


### **Hudson Branch Hydrograph**

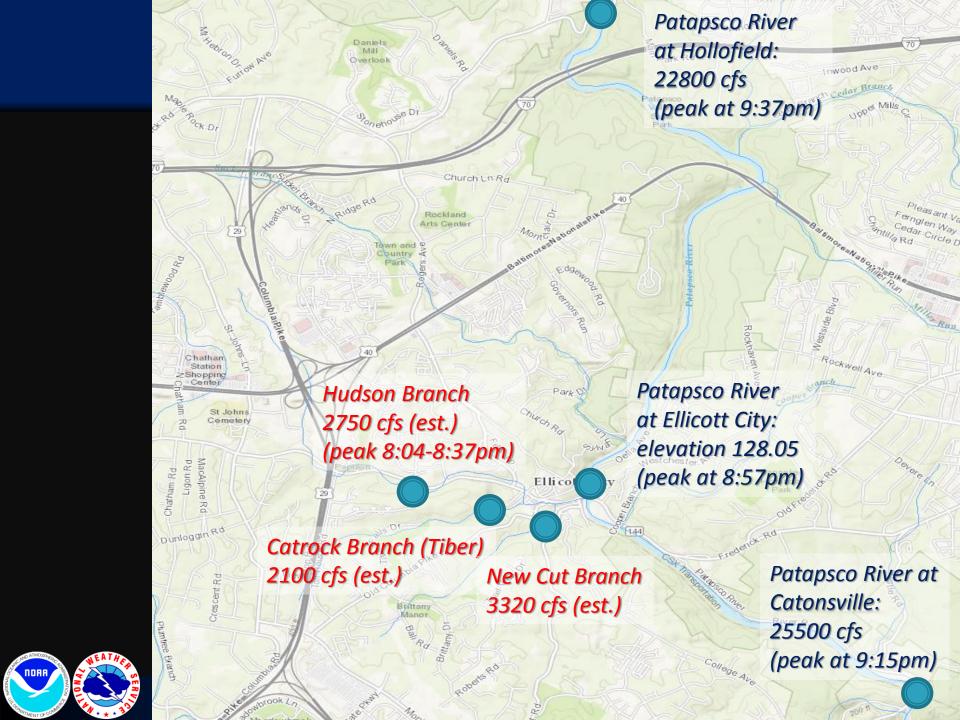




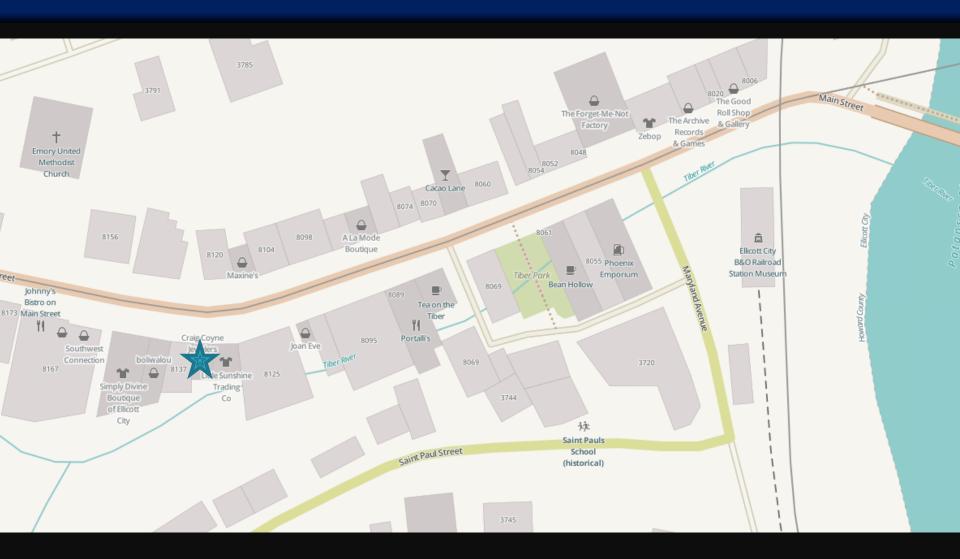
#### **Hudson Branch Hydrograph**



USGS computations: Bridge opening at gauge location can pass 525 cfs Estimated flow on 30 July  $2016 = 2750 \text{ cfs } \pm 20\%$ 



#### **Tiber River**



#### Ellicott City Flood – July 30, 2016

Security camera footage (used with permission)
 Craig Coyne Jewelers, Ellicott City



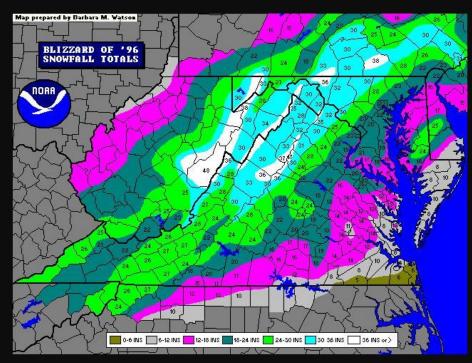




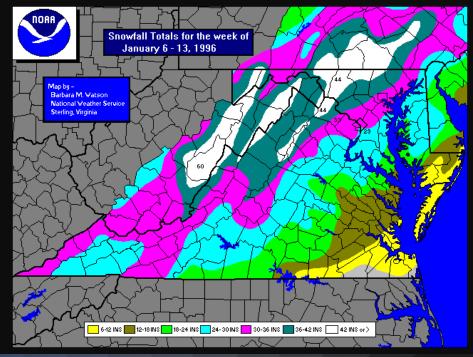
#### Snowmelt

January 1996 Blizzard

#### January 6-13, 1996

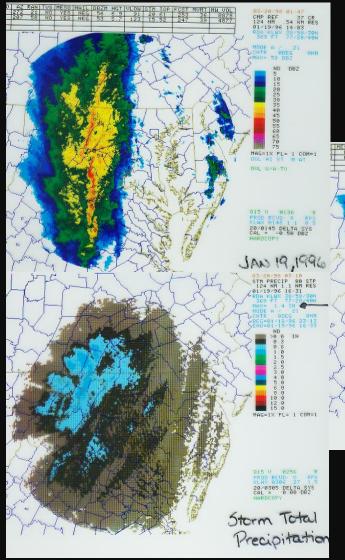


Snowfall from January 6-8, 1996 Blizzard Additional snow fell January 12<sup>th</sup>. Snowfall totals for the week January 6-13, 1996



#### January 19, 1996

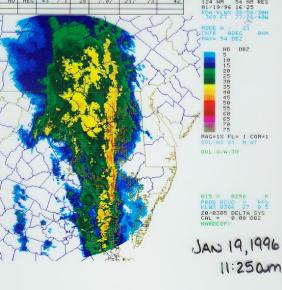
Snowfall at Dulles Int'l Airport (IAD)			
Date	New Snow	Snow on ground (7 am)	
6	1.4	0	
7	19.8	7	
8	3.4	24	
9	0.2	24	
10	T	21	
11	0	18	
12	6.1	19	
13	0	23	
14	0	20	
15	0	14	
16	0	12	
17	0	11	
18	0	9	
19	0	T	
20	0	T	
21	T	T	



Radar images on Jan 19<sup>th</sup>...

-9:03 am (left)

-11:25 am (below)



Radar estimated total rainfall – max 1.4 inches



#### January 1996 event

- ▶ 2 3 feet snowfall early
- Additional snow a week later (less than 1' East & 3' West)
- Water equivalent of snow pack
   2-3" (17<sup>th</sup> & 18<sup>th</sup>)
- ▶ Additional 1 3" rain, locally up to 5"





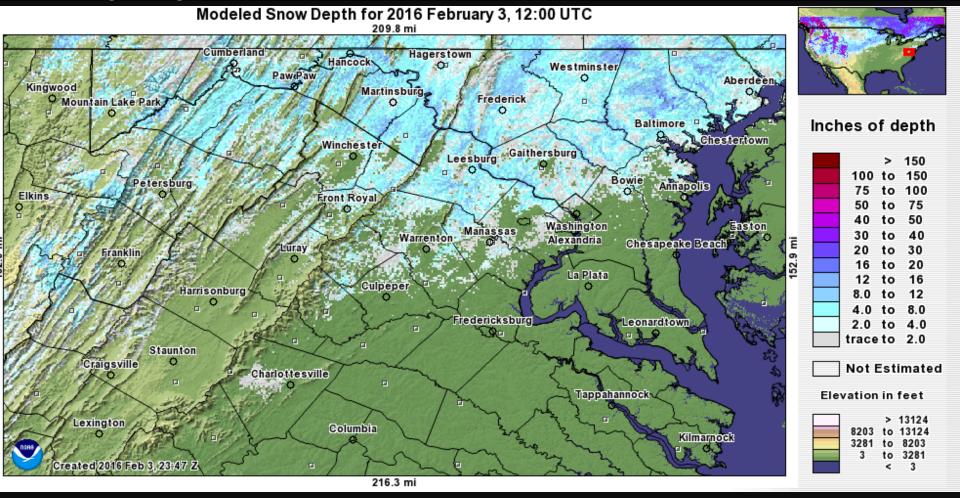
**Above: Shenandoah Street in Harpers Ferry flooded in January 1996** 

Left: Flood Markers on Whites Ferry General Store include the January 1996 flood



#### 1996 Blizzard vs. 2016 Blizzard

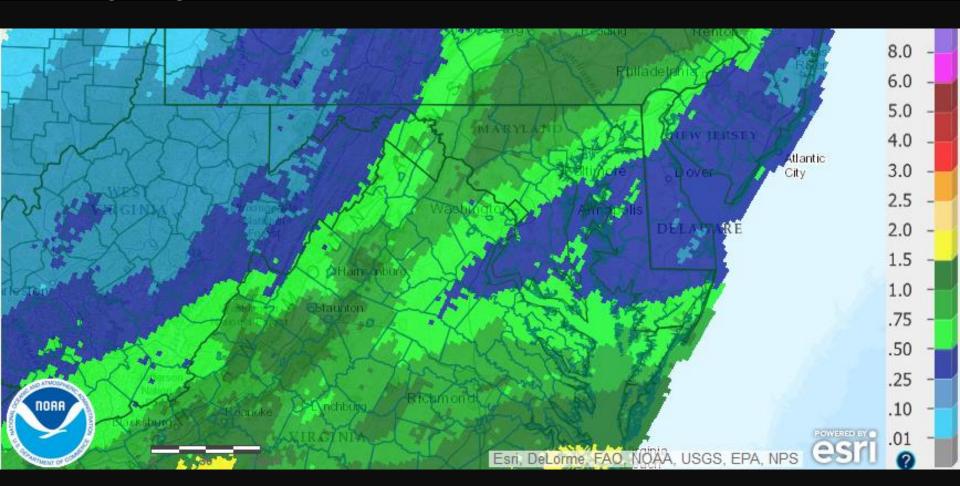
Why no flood this time??





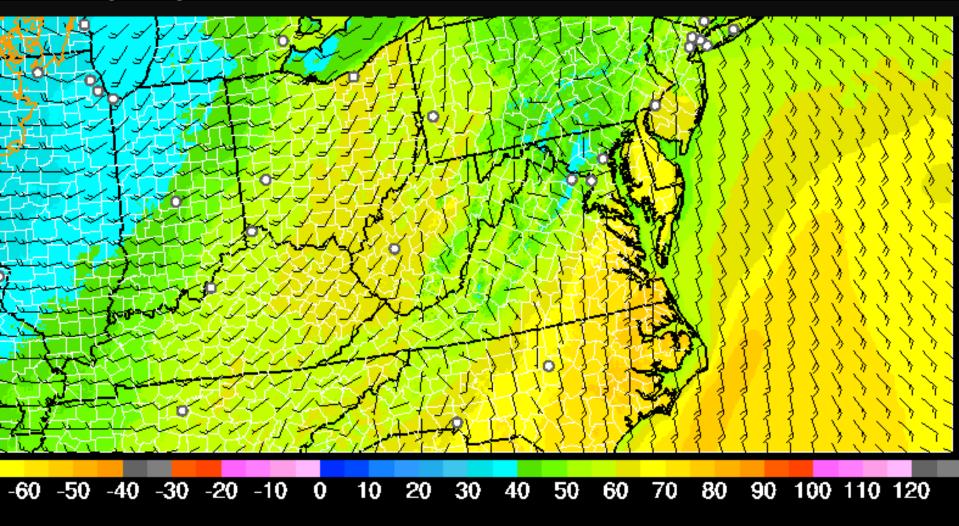
#### 1996 Blizzard vs. 2016 Blizzard

Why no flood this time??



#### 1996 Blizzard vs. 2016 Blizzard

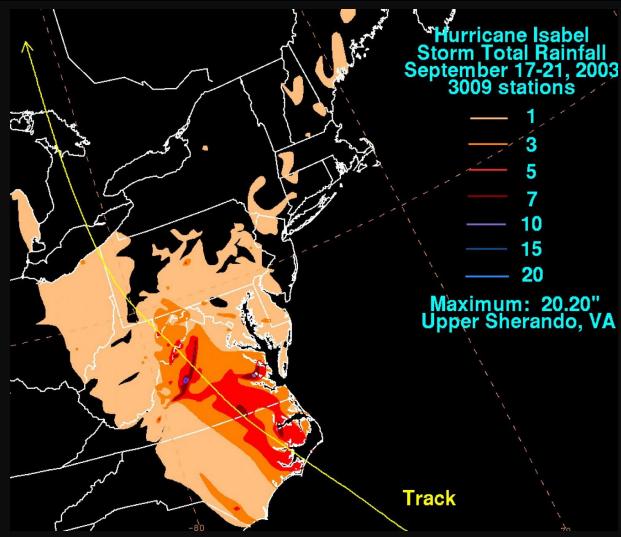
Why no flood this time??



### **Tropical Storms / Hurricanes**

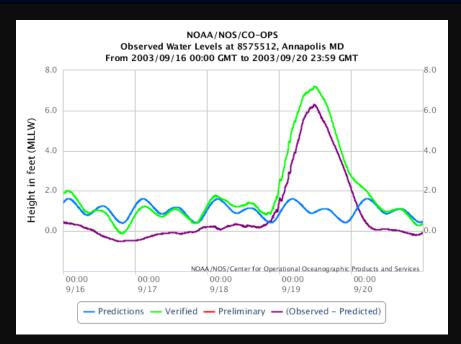
- Isabel (2003)
- 2011 Tropical Systems
  - Irene & Lee

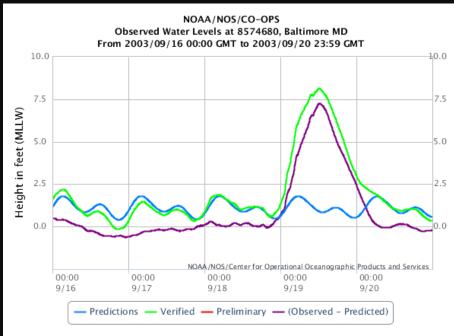
## Isabel (2003)





## Isabel (2003) – Record Tides



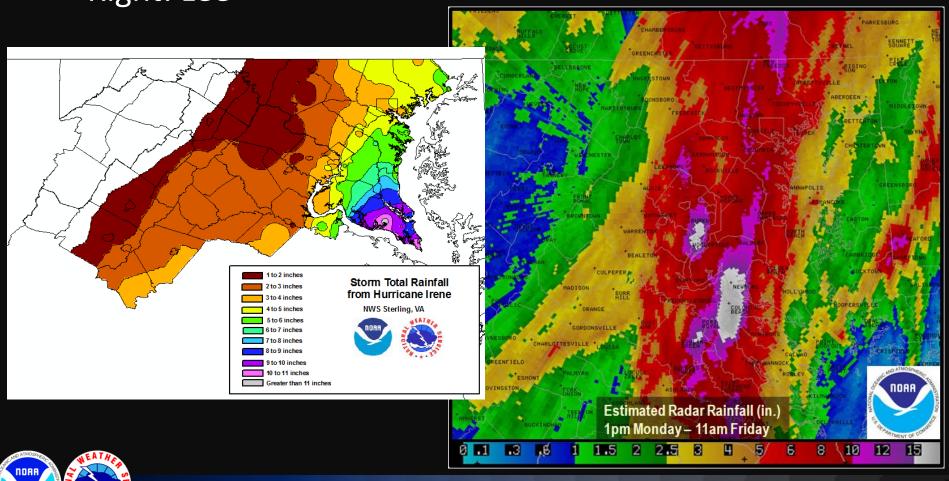




#### **2011 Tropical Systems**

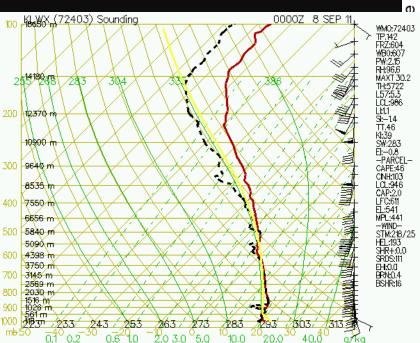
Below: Irene

Right: Lee

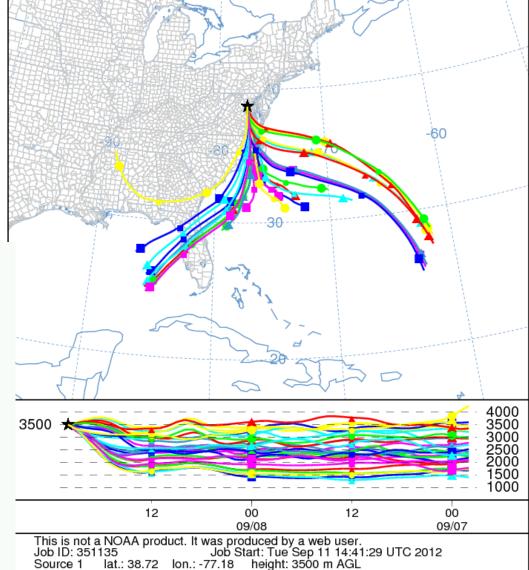


#### The Cause

 Combination of airmasses from the Tropical Atlantic and Gulf of Mexico



# NOAA HYSPLIT MODEL Backward trajectories ending at 2200 UTC 08 Sep 11 GDAS Meteorological Data



Duration: 48 hrs

Model Vertical Velocity



Trajectory Direction: Backward

Vertical Motion Calculation Method: Mo Meteorology: 0000Z 08 Sep 2011 - GDAS1

#### "Lee" Rainfall Totals

Fort Belvoir, VA	13.52"
------------------	--------

- Newington, VA 13.48"
- Franconia, VA
  12.56"
- ▶ Reston, VA 11.97"
- ▶ Waldorf, MD 11.66"
- ▶ Ellicott City, MD 11.36"
- Crofton, MD
  10.21"
- Quantico, VA
  9.39"
- Andrews AFB, MD 9.20"
- ▶ Oakton, VA 7.21"



#### September 2011 flooding – Fairfax Co.

Giles Run at Lorton Road



#### **September 2011 flooding – Ellicott City**



#### Lee Time Lapse



Time lapse photography of the peak flooding associated with Tropical Storm Lee
Sept. 8 2011

Difficult Run, near Vienna, VA
USGS streamgage 1645704
and
Difficult Run, near Reston, VA
Downstream of W+OD Trail

For more information: Ed Schenk eschenk@usgs.gov profile.usgs.gov/eschenk

#### The Last Word

At least one major flash flood happens <u>here</u> every year:

```
    2016 – Ellicott City, MD
```

2015 – Woodstock, VA

2014 – Clear Spring, MD & BWI Airport

2013 – Laurel, MD

2012 – Berkeley Springs, WV

2011 – (widespread flooding from Lee)

But...

Last Major Tidal Flood: 2003

Last Major Potomac Freshwater: 1996

▶ The Potomac floods, on average, every 6-7 years.

We are overdue!!



#### Review

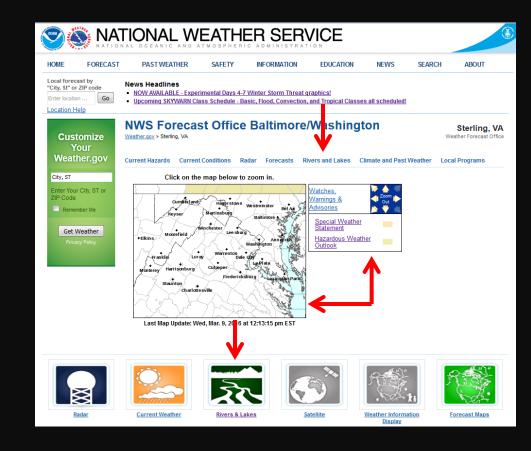
Stay informed via the NWS website.

weather.gov/washington
or
weather.gov/baltimore

Or use...

mobile.weather.gov

for cell phone display



#### Watch & Warning Review

- Hazardous Weather Outlook
  - Detail on flooding potential through day seven.
- Flood Watch
  - Conditions are favorable for flooding. Check the product for threat details (river/flash/areal)
- Flood Warning
  - Flooding is imminent or nearly certain to occur. Take action now!!!

#### Review

- Remember...FLOODING KILLS!
- When a warning has been issued for your area, or you observe signs of imminent flooding, YOU must make the decision to leave flood prone areas and seek higher ground.
- If you are driving and come to a flooded roadway, STOP! TURN AROUND AND GO ANOTHER WAY. (Yes...even if you are a spotter!)



WHEN

**URN AROUND** 

DROWN

#### Review – What to Report

- Heavy Rain measured 1" or more (we like getting periodic reports & a storm total at end)
- Flooding & Flash Flooding Streams, creeks or rivers out of banks or flooding of roads from poor drainage





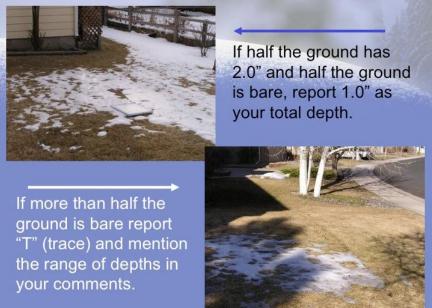
#### **Terminology:**

\* Water over banks but not affecting anything – "bankfull/just over bankfull"
\* Water affecting farmland, roads, property out of floodplain – "flooding"



#### Review - What to report

- Ice Accumulation Any glaze on surfaces (or more)
- Snow Accumulation Every 2" and a storm total, or any accumulation not reflected in the forecast





#### Review – How to report

Call NWS Sterling as soon as you see something:

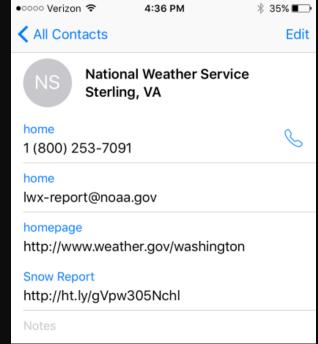
(800) 253-7091

You can email delayed reports or pictures to:

#### LWX-Report@noaa.gov

- Contact local Emergency Management
- Amateur Radio (when activated)

If you see storm damage after the event, let us know! Immediate reports are best; but no report is too late!



#### Questions?

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